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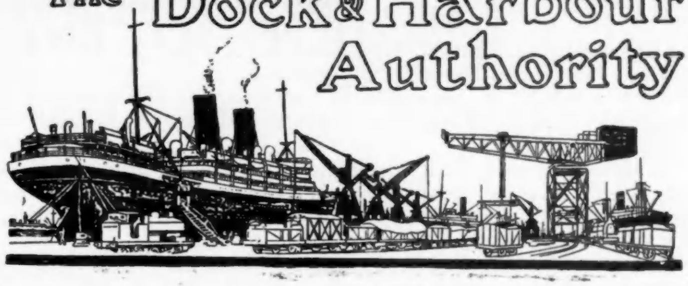

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Editorial Comments

The Port of Karachi.

Situated at the extreme north-west limit of the Indus Delta, in the Sind Province of the Bombay Presidency, the Port of Karachi lies on the left bank of the tributary which enters Karachi Bay, an arm of the Arabian Sea sheltered behind a long narrow sand spit. The port is the natural commercial outlet, not only for the Province of Sind, but also for Baluchistan to the north, and for the great inland wheat district of the Punjab. It is about 500 miles by sea from Bombay and is the nearest Indian port to Aden on the Suez Canal route.

The rise of Karachi, from a straggling village to a modern city with a population of more than 360,000, practically dates from its occupation by the British in 1843, when it was at once chosen for the seat of government for Sind. Since then, it has made rapid progress, and the natural harbour formed by Manora Point has been greatly improved by the construction of extensive port works. Some details of these improvements were given in this Journal in April, 1927, and for the historical account of the development of the port, to be found elsewhere in this issue, we are indebted to Mr. D. B. Brow, who, until recently was Chairman of the Karachi Port Trust.

Since its foundation barely 100 years ago, the trade of the port has steadily developed, one of the chief reasons for this being the great increase in wheat growing as a result of extensive irrigation schemes which have been carried out. Cotton also is collected from all parts of the Sind Province for export and the other principal exports are oil seeds, wool and skins. The chief imports consist of piece goods, sugar, iron and steel, and machinery. The combined total of exports and imports in 1944-5, amounted to more than 2,800,000 tons compared with 2,300,000 tons in 1938-39, and although the increase of 500,000 tons can be largely attributed to the exigencies of the recent war, there is every likelihood that the 1938-39 figures will be exceeded in the future.

Now that British India has been divided into two Dominions, the status of Karachi has been enhanced and it has been declared the capital of the Dominion of Pakistan. It is to be hoped that the present communal strife between India (Hindustan) and Pakistan will speedily be settled and the differences resolved, so that the Port of Karachi can concentrate all its attention and activities on the progressive expansion of the trade which promises to increase considerably within the next few years.

Ports and the Transport Act.

Following consultation with the British Transport Commission recently appointed by the Minister of Transport under the powers conferred on him by the Transport Act, which became law in August last, the Minister has now appointed seven members to serve on the Docks and Inland Waterways Executive. Brief details giving the names and past records of each member will be found elsewhere in this issue.

The bald announcement of these appointments without any accompanying statement of policy, does little to relieve the apprehensions of port authorities regarding their future prospects, and the nature of the administration of ports and of their organisation from a national standpoint, still remains undefined.

In view of this lack of information, what system will eventually be adopted can, at this stage, only be a matter for conjecture, but it is perhaps significant that three of the members appointed to the new Executive have had extensive experience of unified port control. As Deputy Director General of Inland Transport, Sir Reginald Hill was in charge of Port and Shipping Control, the body responsible, through the Regional Port Directors, for the operation and control of the ports during the war years. Two of the Regional Directors were Sir Robert Letch and Sir Hector McNeill.

These appointments may perhaps indicate that the Minister proposes to follow the arrangement which proved successful under the stress of war, and a new system of regional control, on somewhat similar lines, may eventually be evolved. A point which is exercising no little concern among port authorities however, and more particularly the smaller ports, is whether such a system, under peace-time conditions, could be worked economically.

To keep the matter under review, the Chamber of Shipping of the United Kingdom has decided to reconstitute the Post-War Port Organisation Committee which will be supplemented as necessary by drawing on expert assistance from the different districts in relation to proposals which may be under consideration by the new Executive in regard to port organisation on which, in accordance with the terms of the Act, the Transport Commission are required to act in consultation with the Shipping industry.

Scale Models for Hydraulic Research.

The economic crisis has now led to a postponement of many of those large schemes of capital development which we had hoped would give an early restoration of prosperity. Deplorable as this is, it does give technicians an opportunity of improving or reshaping their plans for the future. This opportunity should not be lost.

One of the fields in which planning is of the highest importance is the development of harbours, estuaries and navigable rivers and for this in many cases working models have proved to be of great value. The Government realises this and has endorsed the recom-

Editorial Comments—continued

mendations of the Department of Scientific and Industrial Research for the setting up of a Hydraulic Research Organisation, whose first task will be a new model of the Severn dam to discover how the changes in design will affect the regime and navigability of the river.

Elsewhere we publish an account of a new book by Professor Jack Allen, of Aberdeen University, on scale models for hydraulic research which is most apropos. He had a good deal to do with the first Severn models controlled by Professor Gibson, to whom he was then assistant, and what he has to say on models in general will be of general interest.

There are still some engineers, and many non-technicians, who are sceptical about models and their value, but their number is diminishing. At Rangoon many millions were saved by adopting the conclusions drawn from a model; at Leith Harbour the indications of the model have proved entirely correct; many other examples could be quoted.

Nevertheless it must not be assumed that models are easy to build, operate or argue from. Unless the model is to proper scales, allows for local peculiarities, is adjusted to correct hydrographic conditions, is operated in definite ways and is interpreted according to scientific principles, it will be of little use and it is precisely because of these difficulties that we need good books on the subject.

The cost of models is insignificant compared with the immense sums which may be saved by their use and, whilst even small expenses are of consequence at the moment, it is inconceivable that those concerned will baulk at the cost of undertaking model trials which may and should enable them to set out on large schemes of development with reasonable confidence of success, when the time comes.

The St. Lawrence Seaway.

In our last issue we announced the approval of the St. Lawrence deep-water Seaway project by the sub-committee of the Foreign Relations Committee of the United States Senate.

A further commitment has been made by the Canadian Minister of Transport with the announcement of the award of a five years' contract for dredging the St. Lawrence shipping channel to Marine Industries, Ltd., of Sorel. The Minister, Mr. L. Chevrier, has indicated that future requirements call for the provision of facilities for high-speed 20,000-ton vessels. The largest ships have so far used the St. Lawrence river ports regularly are the Canadian Pacific Steamship "Duchess" class (length 582-ft., beam 72-ft., draught 27.5-ft., tonnage 20,000 gross, speed 16 knots).

He further stated that a survey of the future requirements for the progressive development of these ports and the associated shipping channel showed the necessity for facilities to handle with safety and expedition merchant ships and tankers with lengths up to 625-ft., beams up to 80-ft. and draughts up to 32-ft. with tonnage up to 20,000 gross and speeds of 15 to 20 knots.

"The importance of the St. Lawrence River ports of Montreal, Sorel, Three Rivers and Quebec," he added, "is emphasised by the fact that during the last pre-war year of 1939, the total cargo tonnage of these ports, inbound and outbound (18,816,279 tons) was approximately double that handled by all the other seaports of Canada."

He recalled the four recommendations of the St. Lawrence River Ship Channel Committee of 1946, viz.: (1) Completion of the dredging of the channel to 35-ft. to the 1934 datum and the completion of the widening to 550-ft. with adequate width on curves from Montreal to Quebec. (2) The completion of the widening of the channel below Quebec to 1,000-ft., and deepening to 35-ft. below low water of ordinary spring tides. (3) The increase of anchorage areas in Montreal Harbour to facilitate the handling of ships awaiting berths and the provision of an anchorage area in Lake St. Peter to assist navigation. (4) The deepening of Montreal Harbour basins to 35-ft. at 1934 datum, where required, to provide access to certain piers.

The total expenditure on the Ship Channel from its inception in 1884 to the end of fiscal year 1946-47, was $91,221,463.63, the Minister concluded. The contract just awarded to Marine Industries is estimated at $14,697,769.

All these indications point cumulatively to the urgency which the matter has assumed and to the likelihood of any early materialisation of the project despite the opposition which is being manifested by certain United States ports, the interests of which are affected by the scheme.

Radar and the Export Drive.

The article in our last issue, which described the Radar installation at Wallasey Ferry, has created wide interest, and following enquiries from other Harbour Authorities, demonstrations have been given at Wallasey which have thoroughly tested the appartus under normal working conditions.

A particularly satisfactory demonstration was given towards the end of last month before representatives of the Ministry of Transport. The party, comprising Mr. P. G. Oates, Principal of the Marine Safety Division; Mr. W. Ross, Principal Scientific Officer; Mr. C. S. C. Bridge, Chief Staff Officer of the Docks and Canals Division and Mr. L. S. Le Page, of the Operational Research Office, with Mr. L. D. Price, General Manager of Wallasey Corporation Ferries, inspected the Radar Control Room at the Wallasey landing stage and showed great interest in the operation of the apparatus, which is believed to be the first commercial shore-based installation of its kind in the world. The party was much impressed with the installation, and expressed the view that the technical performance was of a high order and the discrimination and precision of the picture on the indicator compared very favourably with any they had seen elsewhere.

There is no question that the United Kingdom has gained an appreciable lead in the field of Radar as an aid to marine navigation, and in view of the vital necessity for increasing the exports of this country, every effort should be made to bring to the notice of harbour authorities throughout the world the high technical efficiency that the British radio industry has attained. The demonstrations at Wallasey are serving a useful purpose to this end.

Quarterly Shipbuilding Returns.

The statistics issued by Lloyd's Register of Shipping regarding Merchant Vessels under construction at the end of September last show that in Great Britain and Ireland there is an increase of 49,720 tons in the work in hand as compared with the figures for the previous quarter. The present total of 2,112,669 tons gross is also greater by 237,791 tons than the tonnage which was being built at the end of September, 1946, and has not been exceeded since March, 1922, when the total recorded was 2,235,998 tons. It is to be remembered, however, that the continued increase in the tonnage of vessels under construction is necessarily influenced by the delays which present circumstances are imposing upon the completion of ships, and the consequent prolongation of the time required for their building.

The tonnage of Merchant Vessels under construction Abroad at the end of September is shown as 1,856,224 tons gross, which is 72,517 tons more than that recorded at the end of June last, when it was noted that no figures were included for Germany, Japan, and Russia. These reservations still apply, as there are no official figures available. In the case of the latter country however, according to reports appearing in the American press, the United States Maritime Commission estimated that, in April last, the strength of the Russian mercantile marine totalled a little over one-and-three-quarter-million tons, compared with nearly 1,600,000 tons in 1939. The present tonnage, however, includes a number of 10,000-ton liberty ships on loan to Russia under the late lease-lend arrangements and still in operation. A considerable tonnage has also been acquired by Russia as war reparations.

It is also worthy of note that adverse comment has been made in the United States at the continued use of steel for ship construction in Europe while there is a volume of war-built tonnage in the States lying idle and awaiting purchase. This is probably due to the unsuitability of such vessels for particular trades.

The Port of Karachi

Outline History of its Development, 1843-1945

By DAVID B. BROW, O.B.E., M.C., M.I.C.E.
(Late Chairman, Karachi Port Trust).

Early History

THE history of Karachi before the British occupation of Sind in 1843 is dim and uncertain. Alexander Baillie, F.R.G.S., in his " Kurrachee: Past, Present and Future," delved deeply into old records and finally appears to have come, somewhat doubtfully, to the conclusion that the port had been in existence for a hundred years or more before the capture in 1839 of the Fort of Manora, which guarded the entrance to the anchorage five miles from the town. There is, however, little doubt that immediately before the British occupation the town had a population of about 14,000 and its merchants carried on a prosperous overseas and up-country trade. Baillie gives the estimated annual value of that trade as over Rs. 2,000,000, about three-quarters of which was imports. Four-fifths of the imports came by sea from Bombay and consisted mostly of silks and piece goods from various parts of India, from China and from Europe. But the most lucrative imports appear to have been opium and "black ivory." Between 600 and 700 slaves were imported annually, three-fourths of which were young women and girls. Most of them were brought to Karachi from Muscat and other ports on the Arabian coast by Arab dhows. The Arabs traded cloth and dates along the east coast of Africa, obtaining slaves in exchange. As is well known, the slave trade in the Persian Gulf was not completely suppressed until the early part of the present century. The traces of African blood are still very noticeable among the fishermen in Karachi and along the coasts of Sind and Baluchistan.

Occupation by the British

When Sind was occupied by the British just over one hundred years ago, the Port of Karachi consisted of an anchorage only. This was situated in a sheltered lagoon between the islands of Manora and Keamari, and here small sailing ships could ride safely at anchor in almost any weather and at any state of the tide. The anchorage was naturally protected from the open sea by a sandbank, or bar, opposite Manora point, which the larger sailing ships could only cross at high tide. (See plan No. 1.)

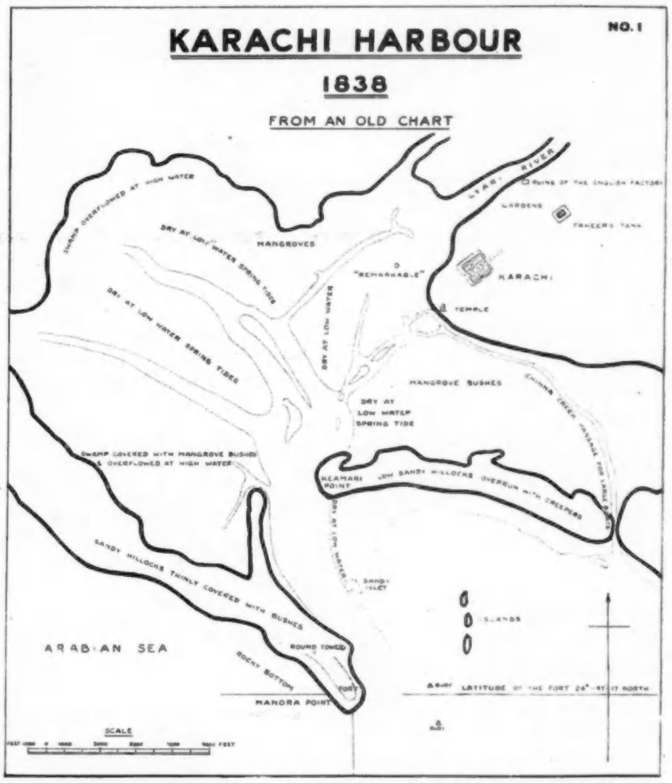
One great disadvantage was that the anchorage was three miles from the mainland by the shortest route, which was along a narrow channel not navigable even for small boats at low tide. The other approach to the town was by the Chinna Creek, three miles to the east of Keamari, which was wider and deeper but involved a circuitous journey of over seven miles. This was probably impracticable except in fair weather, as the entrance, though somewhat sheltered by Manora, was exposed to the open sea. Whichever approach was used, it was necessary to tranship all merchandise and passengers to the mainland by shallow draft "bunder" boats.

The conquest of Sind was virtually completed by Sir Charles Napier in 1843 at the battle of Miani and Sir Charles became the first Governor of Sind under the British Crown. This distinguished soldier and able administrator soon realised the necessity for the improvement of the harbour and during his four years of office he inaugurated preliminary measures in that direction.

First Period (1843 to 1873)

The history of the subsequent development of the port may conveniently be divided into three periods, beginning from 1843. During the first thirty years the harbour was improved so that ocean-going ships could enter in almost any conditions of weather and tide, and, at the same time, the anchorage was deepened and extended. During the next period of forty years, ending with the outbreak of the First World War in 1914, the East Wharves were constructed, while the third period, from then until the present day, is chiefly notable for the construction of the West Wharves.

The first important project, initiated by Sir Charles Napier, was the joining of Keamari Island with the mainland by a causeway or mole, which was completed in 1854. This enabled wheeled traffic to approach within a few hundred yards of the ships' anchorage, and so saved much time in the handling of cargoes. It soon became evident, however, that the trade of the port would not develop to any great extent until ships of greater draught could cross the bar at the entrance to the anchorage. It is recorded that when, in 1853, the first English ship to make the voyage from England to Karachi, the *Duke of Argyll* (800 tons burden), crossed the bar there was only 21 feet of water at high tide, while the anchorage inside was said to be capable of accommodating about twenty vessels of the size of the *Duke of Argyll*. Mr. Bartle Frere (later Sir Bartle) was then Commissioner-in-Sind, the province having become part of the Bombay Presidency, and he initiated the preparation of the great engineering projects which by the end of the first period (1873) had resulted in the deepening of the entrance channel to 29 feet at high water.



After a considerable number of projects and counter-proposals had been prepared and discussed at length in India, it was decided to obtain expert advice from Britain, and an eminent harbour engineer, Mr. James Walker, of the firm of Walker, Burgess & Cooper, and a President of the Institution of Civil Engineers for some years, was consulted. This wise decision had more far-reaching and fortunate results than any previously or subsequently taken by those who have been responsible for the development of the port.

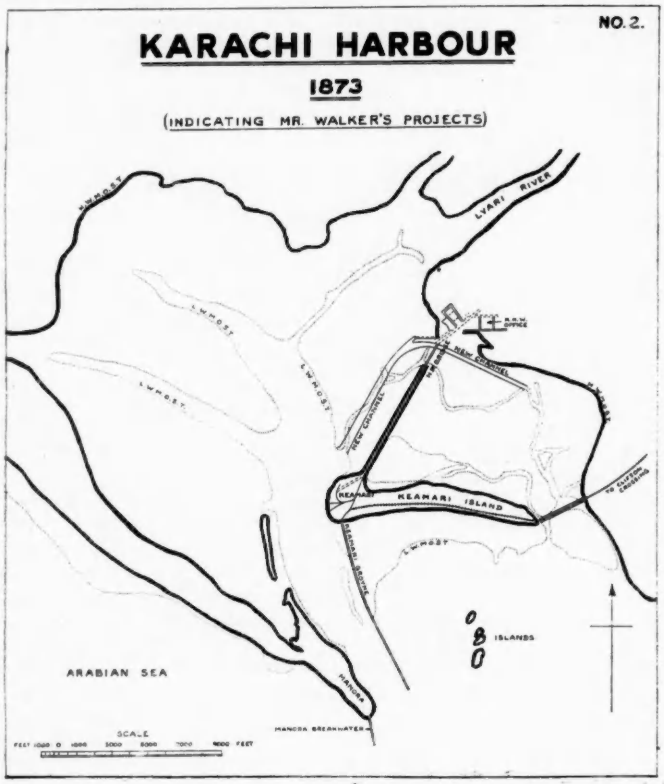
Port of Karachi—continued

Mr. Walker recommended the carrying out of the following works, all of which were finally completed in the years mentioned:

(1) The cutting of an opening in the Napier Mole near the Karachi end and the construction of a bridge across the opening—1864.
(2) Closing the former entrance to the Chinna Creek backwaters from the sea—1863.
(3) Construction of the Keamari Groyne—1865.
(4) Construction of Manora Breakwater—1873.

(These works are indicated on plan No. 2.)

Mr. Walker's schemes came in for much criticism from certain quarters in India, and many years of controversy—sometimes amusingly acrimonious—elapsed before his programme of works was finally adopted. Even then opposition from local officials and engineers in high positions, but with little knowledge of harbour works, succeeded in delaying for many years the completion of the whole programme. However, by 1873 the Manora Breakwater, the last of the works recommended by Mr. Walker, was completed. In the same year, which marks the end of our first period, the Karachi Harbour Board was constituted.



Before going on to the second period, it will be interesting to examine the objects that Mr. Walker had in view in recommending the execution of the above-mentioned works and in what measure those objects were ultimately achieved.

The cutting of an opening in the Napier Mole and the closing of the entrance to the Chinna Creek backwaters from the sea were intended to increase the velocity of the tidal flow between Keamari and Manora, with a view to increasing the depth of water in the channel and over the bar by the scouring action of the tides. Reference to plan No. 2 will show that the Chinna Creek backwaters became by this comparatively simple measure a huge reservoir, which was filled by every flood tide and emptied by the ebb. This almost continuous movement of the water within the harbour prevents the deposit of silt, which is always to some extent held in suspension and which reaches its maximum during the monsoon when the Indus is in flood. On the rare occasions when the Lyari River is also in flood, the amount again increases and in a much greater proportion. Apart from the beneficial results of this tidal action on the depth of the channel, the access of a large volume of clean sea water into the harbour at every tide has a sterilizing and cleansing effect upon the harbour waters, which is of considerable value. There are, in fact, few cleaner harbours in the world.

The other two important works recommended by Mr. Walker, the construction of the Keamari Groyne and of the Manora Breakwater, were designed more particularly to improve the depth of water over the entrance bar. The former was also designed to act as an embankment to prevent sand being washed into the channel from the higher ground on the Karachi side. The breakwater was intended not only to prevent sand being banked up at the entrance during the monsoon, but also to protect the harbour entrance from the ocean swell, which is very heavy during the S.W. monsoon.

The completion of these two important works was much delayed by the criticism and resulting discussions referred to before, but Mr. W. H. Price, M.Inst.C.E., who had been appointed as Port Engineer in 1860 and held that appointment for thirty years, made a very careful study of local conditions while living on Manora, and came to the conclusion that Mr. Walker's projects were sound and that the harbour would derive much benefit from the completion of the groyne and breakwater. By the preparation of elaborate plans and statistics, he convinced Mr. Frere, the Commissioner-in-Sind, of the wisdom of continuing the works, but it was not until some years later that Sir Bartle Frere, now Governor of Bombay, was able to obtain the sanction of the British Government to continue the work. Records show that he had to fight hard against determined opposition in order to obtain the necessary funds, and Karachi is undoubtedly indebted to him more than to any other Government official for the realisation of Mr. Walker's schemes.

The completion of the Manora breakwater in 1873 soon proved that these schemes were sound. Already the depth of water over the bar had been increased by 8 feet without dredging. In fact, no dredging of any importance was carried out until 1898, when the Bucket Dredger, "William Price," arrived from Britain. At that time the depth of water over the bar at low water spring tides was 22 feet, but the channel was narrow and the dredger worked for some years on widening rather than deepening it. The action of the tides, however, continued the process of deepening until by 1933 it was 29 feet below L.W.O.S.T. At this depth the bottom of the channel appears to have become stabilized, but every year dredging is necessary for a few months in order to remove accretion deposited during the monsoon, which tends to decrease the width of the entrance channel on the inside of the bend. The cost of this dredging is, however, infinitesimal compared with what it would cost to maintain the entrance channel at the present depth by dredging, had Mr. Walker's plans not been carried out. It is, in fact, no exaggeration to say that Karachi would never have become a first-class port but for the execution of his plans.

Second Period (1874 to 1914)

Before describing the numerous development works carried out during this period, it may be mentioned that the Port Trust was constituted under the Karachi Port Trust Act passed by the Bombay Government in 1886. The Board consisted of four members nominated by Government and four elected by the Chamber of Commerce and the Municipality, with the Collector of Karachi as *ex-officio* Chairman. In 1902 the number of Trustees was increased to eleven. In 1909 it was decided that it was necessary to have a full-time Chairman, and Mr. H. C. Mules relinquished his duties as Collector and District Magistrate and took over the appointment. By this time Karachi had formally been given the status of one of the four major ports of India.

Up to the beginning of this period, although much capital had been sunk in improving the harbour, no wharves or jetties had been provided to accommodate ocean-going ships. The port was, in fact, merely an anchorage, except that country craft could now more easily sail up the channel to the west of Keamari and unload at a small wharf, subsequently known as the Jhuna Bunder, situated only half a mile from the town.

Port of Karachi—continued

During the period under review, all the East Wharves were constructed and at the same time the Napier Mole was widened by reclamation, in order to provide space for railway sidings, stacking areas and sheds immediately behind the new wharves.

The new wharves were constructed gradually, not only keeping pace with the expanding trade of the port, but somewhat anticipating it. The great bulk of this trade was the export of wheat and the lay-out of the railway service in the Keamari Yard was designed primarily to deal with such traffic. By the end of this period Karachi was the largest wheat-exporting port of the British Empire, having a record shipment of 1,380,000 tons in the financial year 1912-13.

Works Constructed During Second Period

(1) Merewether Pier—to berth one large ocean-going ship—built in 1882. (Subsequently dismantled.)
(2) Erskine Wharf—3 berths—1888.
(3) James Wharf—3 berths—1895.
(4) Giles Wharf—3 berths—1906-1907.
(5) Younghusband Wharf—4 berths—1908-1910.

(These Wharves were all named after Commissioners-in-Sind.)

The two oldest of the above, i.e., the Merewether Pier and the Erskine Wharf, were reconstructed in 1908-1909 in line with the newer wharves. The former became the Merewether Wharf with accommodation for four ships. The total number of deep-water berths in existence in 1910 was therefore seventeen, in one continuous line of wharfage 8,600 feet in length. All the wharves were supported on solid steel screw piles, 5 and 6 inches in diameter, the decking being of built-up girders and joists covered with 6-inch timber planking. All were completely served with railway feeder lines and equipped with hydraulic cranes, of which there were 87 of 35-cwt. capacity, one of 30 tons and one of 14 tons. All the berths were gradually dredged to give a depth of water of not less than 27 feet at L.W.O.S.T.

In 1909 the Bulk Oil Pier was completed and joined up by separate pipe lines to the installations of the Burmah Oil Company, the Standard Oil Company of New York, and two smaller installations subsequently taken over by the larger concerns.

Other works carried out during the last few years before the World War of 1914 were the following:—

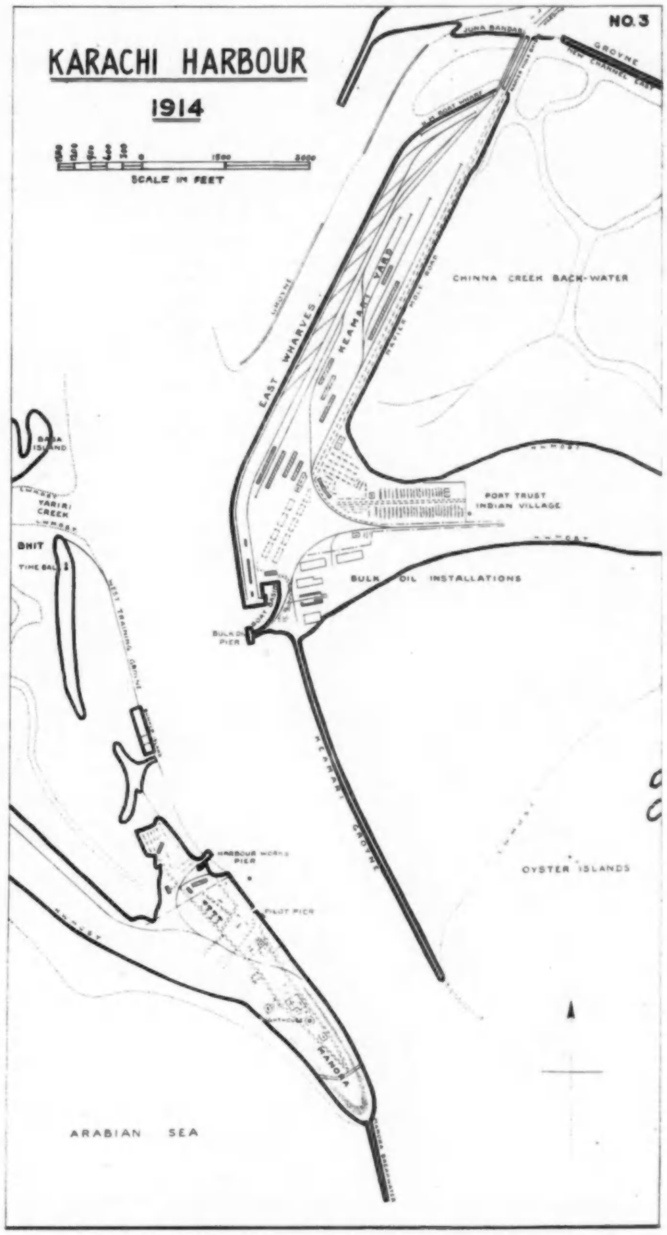
(1) Boat Basin.—11 acres in extent, for landing and embarking passengers and goods from and on to vessels anchored in the stream. Around all three sides of the Basin were built the Return Wharf, Sydenham Pier and the Railway Wharf.

(2) Manora Lighthouse—completed by the Port Trust in 1909—was at that time one of the most powerful in the world, the light being visible in clear weather at a distance of 18 miles and the loom anything up to 70 miles. In 1914 the Cape Monze Lighthouse was built by the Government of India, and subsequently a light-ship was provided and stationed near the delta of the Indus 55 miles south of Karachi. This vessel, however, was not used during the first or second world wars, nor is it left out at sea during the monsoon months. During the " fair season " months of the year mist is more likely to occur, and the light-ship is then a considerable aid to ships making the port from the south and those going in and out of the Gulf of Kutch.

(3) Napier Mole Boat Wharf.—A short length of wharf to accommodate country craft had been provided early in the history of the port. This had been increased to 1,824 feet by 1914.

(4) The Chinna Creek Railway Bridge, constructed between 1910 and 1914 by the North-Western Railway, greatly improved railway service to the Keamari Yard and East Wharves. Before this, service had been by a circuitous single-line route via Keamari. The new bridge provided for two main lines and an additional line for local shunting operations.

(5) Graving Dock.—Owing to the increase in the activities of the port and the acquisition of tugs, dredgers and other harbour craft, a small graving dock was constructed at Manora in 1901, together with ancillary workshops, which have since been much expanded.



(6) Land Reclamation.—In 1909 a start was made with the acquisition of land required to provide for future expansion by the purchase of 177 acres of tidal swamp from the Karachi Municipality. This was reclaimed and became the Thole Produce Yard. Then followed the reclamation of 61 acres upon which the Mansfield Import Yard was laid out and a further 115 acres between Keamari and the Chinna Creek, which enabled extensions of the railway yards in that area to be carried out. By the end of the period over 350 acres of potentially very valuable land had been added to the assets of the port.

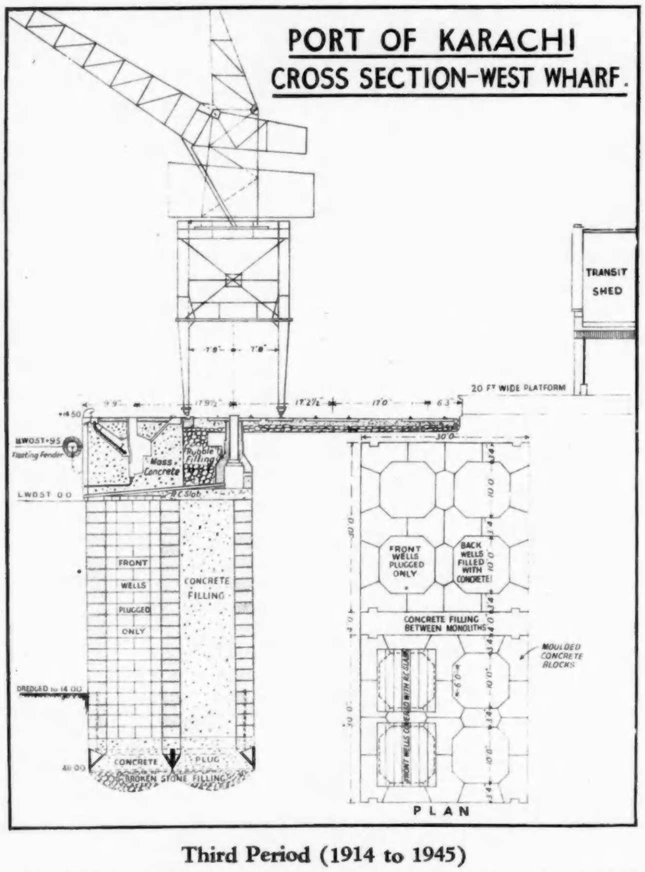
(7) Dredging.—While these developments on land were proceeding, the work of deepening the channel and moorings

Port of Karachi—continued

was undertaken. Although the scouring action of the tides was continuing to improve the channel throughout the period, the depth was not uniform and certain places had a tendency to silt up. After 1898, when the bucket dredger "William Price" began work, there was a more rapid increase in the deep water areas, as will be seen from the following table:—

	1874	1884	1894	1904	1914
Area of water 25 feet and more below datum (acres) ...	48	53	115	234	395
Area of water 27 feet and more below datum (acres) ...	28	36	48	85	219

The outbreak of the first World War, which marks the end of our second period, found the port well equipped to become, as it did, the main base for operations in Mesopotamia (Iraq). Its claim to be the third port of India was by then well established.



Third Period (1914 to 1945)

Mr. Mules, later Sir Charles Mules, C.S.I., M.V.O., O.B.E., was Chairman of the Board of Trustees until 1919, when he retired. In 1925 the number of Trustees was increased to fourteen, and in 1933 this number was further increased to fifteen.

In 1936, consequent upon the separation of Sind from the Bombay Presidency, the Karachi Port Trust was placed under the direct control of the Government of India.

Little new development work was carried out between 1914 and 1920, but a new suction dredger, the powerful "Graham Lynn," had arrived in 1915, having fortunately been ordered well before the outbreak of war. This was kept steadily at work during the war on widening the upper channel and pumping the spoil ashore for land reclamation on the west side of the channel, an essential preliminary to the construction of wharves and railway yards on that side. Towards the end of 1919 the late Sir Frederick Palmer, C.I.E., M.Inst.C.E., the eminent Consulting Engineer, was asked to advise the Trustees regarding future developments. He visited Karachi three times during the cold weather of 1919 to 1920, and in September, 1920, he forwarded a comprehensive and most valuable report covering the whole field of future developments.

The Port Trust was in a strong financial position at this time, and there were optimistic predictions about the future expansion of trade. The Trustees therefore decided to embark upon the most important of the projects recommended by Sir Frederick—the construction of a deep water quay wall on the west side of the upper harbour.

Detailed plans were prepared and specially designed constructional plant was ordered from Britain. By 1921 sufficient land had been reclaimed and roads and railway lines laid to enable work at the site to be started.

West Wharfage Scheme

The new quay wall was designed according to what was at that time the last word in deep-water wharf construction. The foundation consisted of a line of cement concrete monoliths, each measuring 30 feet square in plan, the depth below low water varying between 42 feet and 48 feet, according to the nature of the ground. Although this type of quay wall has been built in many ports in Great Britain and India, the method of construction is not well known. A few technical details may therefore be of interest.

A monolith, when the term is used in this connection, is rather like an enormous box sunk into the ground. During the process, the ground under the monolith is removed by excavation through two, four, six or more separate wells extending from the top to the bottom of the monolith. As the ground is removed, the monolith is supposed to sink gradually by means of its own weight, assisted, if necessary, by loading it with heavy weights. If, however, the ground is very hard, sinking is sometimes slow, and, in order to get it down, other less orthodox methods have to be adopted. On other occasions monoliths have been known to sink several feet in a few seconds. After each monolith sinks 12 to 15 feet, it is built up from above and then further excavation continues. When the required depth is reached, the wells are sealed or plugged with cement concrete to prevent further settlement.

After the monoliths have been plugged, the quay wall, consisting of a solid mass of concrete, is built upon the foundation of separate monoliths, usually spaced from three to six feet apart. The spaces are finally sealed with cement concrete. It will be understood that this method of construction produces a quay wall which is practically indestructible, and costs nothing for maintenance. The only disadvantage of the system is due to the practical difficulties often experienced in sinking the monoliths, which results in the capital cost being heavier than for other forms of construction. Although the final result is excellent, most port engineers nowadays would probably advocate a less costly form of construction.

The first two berths of the West Wharf were completed in 1927 and one year later electric cranes of two tons capacity and spacious transit sheds had been added, together with the usual rail and road facilities. Two other berths were completed in 1929, but were not equipped with transit sheds nor with cranes. Up to this time Rs. 88 lakhs (£660,000) had been spent on the West Wharfage Scheme and, as the post-war trade boom was showing signs of declining, further construction work was postponed. Land reclamation was, however, very wisely continued until 1936, by which time an additional area of nearly 200 acres over and above the 1914 figure had been made available for future development at an average cost of about Rs. 2/- per square yard. Most of this earned no revenue for some years, but it was invaluable during World War II, practically all vacant areas being used by the Defence Services.

Other Improvements

Although little important construction work other than reclamation was carried out between the years 1930 to 1941, many renewals, replacements and improvements were effected and the port installations were maintained in a high state of efficiency. One notable improvement was the installation in 1936 of

Port of Karachi—*continued*

electrically-operated turbine pumps for the generation of hydraulic power for all the cranes at the East Wharves in place of the old steam plant.

An additional berth at the West Wharf was equipped with electric cranes in 1939.

The Second World War

During the first two years of World War II the possibility of Karachi having again to function as a strategic port was never seriously considered, and, as all non-essential expenditure was cut down under Government orders, no new works of any magnitude were undertaken. Pearl Harbour (December 7th, 1941) and subsequent events immediately altered the whole situation. All Eastern ports beyond the frontiers of India were soon dominated by the Japanese, and Karachi, in common with other ports in India, and more particularly those on the West Coast, was suddenly called upon to handle an enormously increased volume of imports, most of which were materials essential to the war effort. Much of this was frustrated and diverted cargo, and by May, 1942, there was no less than 60,000 tons of such cargo lying on the premises of the port. In many cases the relative shipping documents had been lost and often marks had been obliterated or were illegible. The work entailed in sorting out and finally disposing of this vast accumulation of goods was enormous and was not completed for many months. Meanwhile there was a rapid increase in imports required to meet the needs of the Fighting Services based in India.

The most remarkable increase was in the volume of heavy lifts. These were dealt with in some cases by ships' derricks unloading overside into lighters, but more often by the one and only floating crane belonging to the port—the 30-ton "Pahlwan II." (A second floating crane of 60 tons capacity was obtained from the U.S.A. in 1944 and was named "King Kong.") Other cargo was also, whenever possible, unloaded overside into lighters by ships' derricks, while at the same time wharf cranes were unloading into transit sheds, railway wagons or road transport.

Lighterage

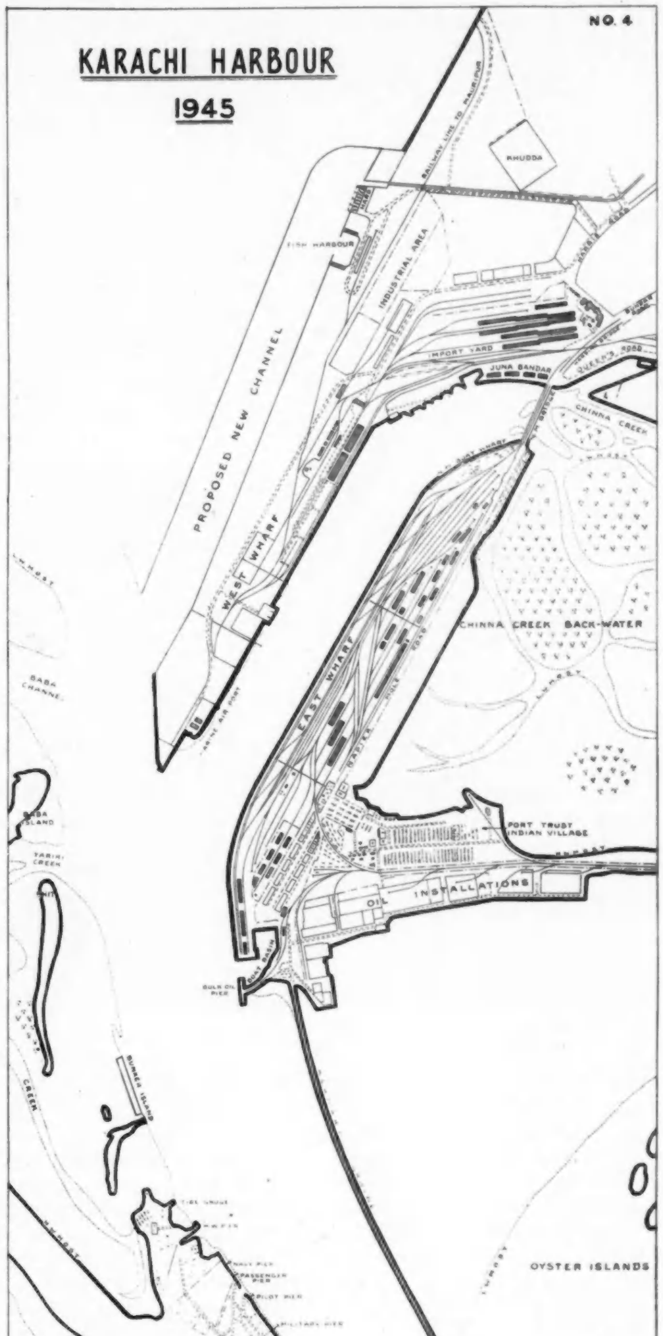
By the middle of 1942, it was realised by the staff of the Port Trust that the most urgent need of the moment was the provision of additional lighterage facilities, including wharves, cranes, lighters and tugs. Steps were at once taken to construct or provide these.

(a) **Wharves.**—Plans were prepared for the construction of 900 feet of lighterage wharf, but practically no suitable material could, for some months, be obtained. Structural steel was absolutely unobtainable, but fortunately among the frustrated cargo there was a consignment of 600 tons of Lease-Lend steel piling which had been destined for Surabaya (Java). There was considerable doubt as to the ownership of the consignment, and enquiries relating thereto looked like being protracted. It was therefore decided with the concurrence of the Q.M.G. and the D.G.M.P. to use some of it for the foundations of the new wharves. (There were some slight repercussions many months later when the Admiralty claimed the piling.)

Another difficulty was to find steelwork suitable for beams, bracings and tie-rods, but this was finally solved by joining up lengths of scrap rails torn up from sidings which were not absolutely essential. The superstructure was of concrete and masonry, and a quantity of cement, also obtained from frustrated cargo, enabled work to proceed without undue delay. The first length of 250 feet of wharf was in use by October, 1942, and by August, 1943, a total length of 900 feet had been completed.

(b) **Cranes.**—An indent for ten mobile and loco cranes was placed in June, 1942, and this was increased to sixteen by the Anglo-American Mission to Ports in December, 1942. Only four mobile cranes were received by February, 1943, and three of these had to be sent to another port. Four mobile cranes were received in October, 1944.

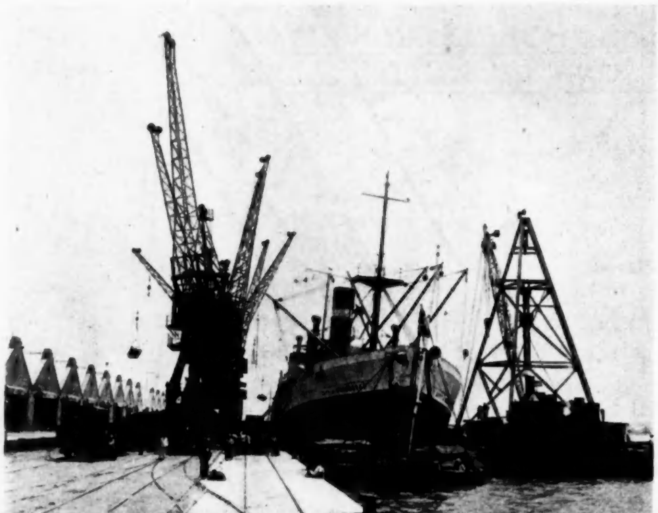
The Port Trust had also asked in June, 1942, for two additional floating cranes, but the "King Kong" was only handed over to the port in December, 1944.



Port of Karachi—*continued*

Meanwhile seven old 5-ton steam cranes, which formed part of the constructional plant for the West Wharf and had been stored for 15 years, were reconditioned. One of these was a travelling Scotch derrick, five were of the Goliath pattern, and one was an ordinary loco crane. One 25-ton electrically-operated derrick crane, which had been used on the Sukkur Barrage construction, was hired from the Sind Government. Other heavy lift travelling cranes were hired from the North Western Railway from time to time.

These old cranes were far from ideal for the work in hand, but they saved the situation, and it was very rarely that lighters were held up. The Scotch derrick rendered great service and by working three shifts daily managed to clear an enormous number of aircraft cases. Although nominally of 5-ton maximum capacity, most of the lifts handled were of about 7 tons, and after some months the jib of the crane showed signs of buckling. It was stiffened up and work proceeded as usual after two or three days.



General view of West Wharves, Karachi.

(c) **Lighters.**—These were loaned from various sources while wooden lighters were constructed locally, which, however, were not a great success, suitable timber not being available.

(d) **Tugs.**—One tug, normally used mostly on dredging, was utilised, and also a self-propelled dangerous cargo barge. A grab dredger was also used both as a tug and a lighter by decking over the hoppers. Additional tugs had been indented for in June, 1942, but were not delivered until early in 1945.

Oil Bunkering

The sinking of a large number of the older merchant ships during the first two years of the war and their replacement by new vessels of the *Liberty*, *Victory* and other classes, mostly built in the U.S.A., increased the proportion of oil-burning vessels visiting the port to two or three times the pre-war figure. Before 1942 only five berths out of a total of 22 were served with oil-bunkering pipelines, but early in the war it had been decided to duplicate the existing pipelines so as to provide for simultaneous bunkering and discharging. This work was delayed owing to the difficulty in obtaining pipes, but was completed in March, 1942. Meanwhile pipes were also ordered for extensions, which were carried out gradually as deliveries were obtained. By February, 1944, eleven berths were served with double pipelines.

An oil-bunkering barge of 500 tons capacity was also ordered in June, 1942, but here again, owing to the delivery of the necessary structural steel not having been given very high priority, the barge was not completed until nearly the end of 1944.

Capacity of the Port

Towards the end of 1942 the Joint Anglo-American Mission on Ports visited Karachi and made full enquiries into the estimated capacity of the port to deal with war traffic and the possibilities of increasing that estimate. The Mission came to the conclusion that the maximum capacity of the port at that time was about 8,000 tons of imports and exports daily, and that, after the additional cranes, lighters and tugs, which it was agreed were necessary, had been provided, the maximum capacity might reach 10,000 tons daily. It was, however, admitted that this figure could only be reached if the North-Western Railway were able to provide sufficient rolling stock to deal with such a volume of traffic.

In August, 1943, the Traffic Manager, Karachi Port Trust, in the light of experience gained during the previous six months, reported that, subject again to sufficient rolling stock being available, he estimated that the maximum capacity might reach 12,000 tons daily. This estimate was also subject to the condition that two of the four berths, then being continuously occupied by ships under repair, were released for working cargo and that the new cranes, lighters and tugs, on order, had arrived.

Although these berths never were released, the total exports and imports during the last financial year of the war (1944-45) reached the record figure of 2,800,000 tons, giving an average daily figure of 7,800 tons, including all holidays and a number of rainy days when work was practically at a standstill. The target figure of 12,000 tons was exceeded on a number of days in the year, although little of the promised new equipment had arrived and heavy lifts had to be handled by the improvised methods already described.

Ship Repairing—Merchant Service

During the first two years of the war the amount of merchant ship repairing carried out at Karachi was little more than it had been in peace-time, and consisted almost entirely of ordinary running repairs. No special ship-repair berths existed and only two or three firms were in a position to undertake structural repairs. Early in 1942 the Port Trust was asked to extend in every possible manner the existing facilities for the repair of merchant ships.

At that time the tonnage of exports and imports over the East Wharves was considerably below the normal peace-time figure, and it was accordingly decided to utilise four of the older berths for ship repairing. In addition to these berths, which were more or less permanently allocated to the Director of Merchant Ship Repairs, other berths were used for this purpose whenever they could be spared, and by double banking there were, during 1943 and 1944, usually fifteen or sixteen and sometimes as many as twenty ships all under repair at the same time. The Port Trust also constructed a special berth for ship repairs on the west side of the Upper Harbour and leased land nearby to three engineering firms, which were principally engaged upon ship repairs and later upon new construction work.

The new road which had been constructed along the East Wharves was of great assistance to the firms engaged upon repair work, and they also had the use of the wharf cranes whenever required. The Port Trust further provided a special feeder line for the supply of electric power for welding sets and air compressors used upon this work along the East Wharves.

A number of badly damaged ships were dealt with, including several ex-German and Italian ships captured in the Persian Gulf.

A summary of the work carried out up to the end of September, 1945, is as follows:—

Merchant Ships Repaired (completed).

	Number.	Gross Tonnage.
1942	154	929,500
1943	305	1,665,400
1944	387	2,316,000
1945 (9 months) ...	260	1,574,000

Ship Repairing—Naval

One of the major activities of the Engineering Department of the Karachi Port Trust during World War II was repairing ships of the Royal Indian Navy. Before the war it was only on rare occasions that naval vessels were dry-docked at Karachi, and in

Port of Karachi—*continued*

1939 there was only one instance. In 1940, however, nine ships were docked and the number gradually increased as workshop facilities were improved. During the last three years of the war practically all naval vessels based on Karachi and Persian Gulf Ports were dry-docked and repaired by the Port Trust. There being no naval dockyard at Karachi, the Port Trust dockyard, in effect, functioned in lieu thereof.

In order to do so, it was necessary to modernise the workshops and build a fitting-out jetty. Two L/L electric generators were installed adjacent to the Machine Shop and a number of electrically-operated machine tools were acquired. During busy periods work went on day and night, and peak capacity reached four times the pre-war figure. In addition to the naval work, all the harbour craft of the port had to be kept in such a condition that they could cope with the greatly increased work of the port.

The Future

The ordinary overseas trade of the port has increased rapidly since the conclusion of hostilities, but it seems improbable that the tonnage figures of 1944-45 will be equalled for some years to come. Measures to increase the capacity of the port can, therefore, be deferred for the present. The reconstruction of the East Wharves and the re-modelling of the Keamari Yard should, however, be taken in hand, because some of the wharves are fifty years old and maintenance costs are excessive. The reconstruction of these wharves and the provision of modern cranes would probably add 50 per cent. to existing capacity, so that additional wharfage would not be needed for some years.

Housing is the most urgent post-war problem. The Trustees forty or fifty years ago accepted the responsibility for providing quarters for their regular employees and built about 1,000 quarters at Keamari and 250 at Manora. Unfortunately, the building of quarters thereafter did not keep pace with the growth of the port, and, although an effort was made to make up the deficiency between 1937 and 1940, there was still a shortage of accommodation when Japan entered the war and all non-essential building work was stopped. Since then the situation has become much worse. Not only is there a grave deficiency of accommodation, but many of the houses are now due for reconstruction owing to their dilapidated condition.

Land Reclamation

Land reclamation has been going on steadily since May, 1943, when a suction dredger, belonging to the Sind P.W.D., was chartered. At the same time a new channel is being dredged, which will be used by fishing boats and country craft, so relieving the congestion which now exists in the Upper Harbour. This scheme is indicated on Plan No. 4.

Proposed Dry Dock

From time to time the construction of a dry dock, large enough to take any ships likely to visit Karachi regularly, has been considered. At the request of the Trustees their Consulting Engineers, Messrs. Rendel, Palmer & Tritton, prepared in 1924 complete designs for a dock of the dimensions then considered suitable, which were:—

Length	620 feet
Breadth	80 feet
Depth (overall) ...	25½ feet (at H.W.O.N.T.)

The estimated cost was Rs. 33 lakhs (£247,500). After careful consideration it was decided that, as Karachi is not a terminal port, a dry dock of such dimensions would not be a commercial proposition and the project was abandoned.

In December, 1941, immediately after Japan entered the war, the possibility of constructing a dock of similar dimensions was reconsidered, and the Port Development Committee recommended that, if Government assistance were forthcoming, the project should go ahead, with the proviso that the Port Trust share of the capital cost should be limited to Rs. 33 lakhs. Messrs. Rendel, Palmer & Tritton were consulted as to design and asked to contact the Admiralty regarding priorities and financial assistance. They produced plans for a "Quick Construction Dry Dock" of ingenious and unique design. Reinforced concrete cells were to be pre-cast in units away from the site while dredging was proceeding, and it was estimated that, providing the highest priorities were afforded both in India and the U.K., the work could be finished within one year. Reduced copies of the complete plans, with specifications and diagrams of the methods of construction proposed, arrived on thirty airgraph letter sheets by the end of March, 1943. In order to meet Admiralty requirements, the dimensions had been increased to 650′ × 80′ × 35′ overall. This would have added considerably to the cost, which was estimated at a crore of rupees (£750,000) at least, and, in view of the subsequent inflation of prices in India, this would no doubt have been greatly exceeded. The project would nevertheless have almost certainly been carried out had the British Admiralty and the Ministry of War Transport been able to allocate the necessary labour and materials. At that time, however, there were many other proposals requiring priority consideration in London, and it was not surprising that instructions were received in July, 1943, to abandon the project.

General view of East Wharves, Karachi.

Among post-war schemes a dry dock takes high place, but no decision has yet been taken regarding dimensions. The provision of a dock to take coasting steamers and R.I.N. ships up to 5,000 tons is considered a reasonable commercial proposition, but it seems unlikely that anything much larger will be undertaken for some years to come.

The Marine Airport

Karachi is the most important base in India for both land planes and flying boats of the B.O.A.C. Until 1945 the upper channel of the harbour was used as an alighting area. This was never very satisfactory either from the point of view of the Port Authorities or of the B.O.A.C. The alighting area was of insufficient length for fully-loaded Sunderlands to take off safely and there was always the risk of collision with small surface craft when alighting, particularly at night.

Accordingly when, after the war the R.A.F. gave up the use of Karangi Creek, situated about 10 miles to the east of Karachi Harbour, the B.O.A.C. arranged to lease from Government this excellent alighting area. The only disadvantages of Karangi are its distance from Karachi and the unsatisfactory state of the road therefrom after heavy rain. This however is being remedied gradually.

Conclusion

Karachi is now the capital of Pakistan and there can be no doubt that as soon as the present communal difficulties are resolved the trade of the port will increase rapidly. There is no reason to anticipate that administration will suffer from recent changes. On the contrary, if the Port Trustees are no longer hampered by out-of-date legislation enforced by officials in Delhi, then there is no doubt that the port will continue to be developed and improved in order to cope with the expansion of trade which can confidently be anticipated for some years to come.

The Development of Dry Docks

By H. RIDEHALGH, A.M.I.C.E.*

Early Construction

Sir Cyril Kirkpatrick's lecture[1] on the Development of Harbour and Dock Engineering before the Institution of Civil Engineers in 1926, opened with an excellent historical note on the growth of naval and commercial shipping from earliest Egyptian records onwards and the importance of our maritime supremacy throughout the ages was clearly demonstrated. A much later demonstration of the necessity for this supremacy was forthcoming during recent war years.

Facilities for ship repair have grown colaterally with construction and the dry dock has consequently developed into the most important port facility for such repair work.

There is little doubt that vessels were, in the early days, put ashore on suitable beaches at high tides and careened for bottom scraping and repairs, the sequel to this being to exclude the rising tide by surrounding the beached vessel with walls of brushwood and puddled clay. Some of the earliest writings indicate that this method did not long survive and primitive forms of slipways with equally primitive hauling arrangements, as depicted by de Belidor[2], were in universal use up to the 14th century although even as late as 1434 it is recorded that the naval vessel "Grâce Dieu" was beached and surrounded by puddled walls for repairs near Southampton. The first recorded construction of a dry dock in this country was at Portsmouth in 1495-96, the dock being rectangular in plan with two piled cut-offs across the entrance several feet apart, the space between them being filled with clay and stones after the vessel had entered. Such was the magnitude of this seal that men are stated to have worked for 29 days on the tides removing piles, clay and rubbish at the entrance before the docked vessel could be taken to sea.

Around this period there is confusion in the use of the word "dock" which was applied loosely and included tidal and protected building slips and wet as well as dry docks, making it most difficult to trace development. The condition "dry" incidentally was maintained at this time by the use of Archimedian and other primitive hand-operated screw pumps, although in almost all cases, the floor was given a good fall to about mean sea level at the entrance and little pumping was required.

The "Gabriel Rialls" was docked on wooden blocks at Woolwich in 1518 and dry docks existed at Chatham and Deptford in 1653. A new dry dock was ordered at Portsmouth in 1666 at a cost of £2,100, but the clearest record of an early dry dock in this country is at the Howland Wet Dock on the Thames in 1703. There was established there, two dry docks, the largest 247-ft. long, 44-ft. wide "with 16-ft. 6-in. draught of water at good spring tide,"[3] capable of receiving two of the largest merchant ships of that time and a smaller dry dock 140-ft. long of similar width and entrance depth. From the notes it would appear that entrance was only possible near the top of the tide and when docked the hull of the vessel stood well above the cope from which level it was shored. Even at this date it would appear that dry docks were little more than modified slipways, the upper portion of which was walled in with vertically sheeted timber or masonry and sealed off with double leaf timber lock gates which were introduced in this country on the canals during the 16th century. No doubt the longitudinal fall in the floors of some modern docks is in part a perpetuation of its slipway origin.

The vertically sided dock soon gave way to the almost saucer-shaped cross-section, primarily to cut down pumping, but also to provide better working conditions for those engaged on caulking and painting the curved timber hulls. With the advent of deeper draught merchant and naval vessels and consequently deeper docks it became no longer possible to shore from the cope and the altar was introduced for this purpose. The saucer type cross-section had several disadvantages, chief of which was the lack of level working areas on the dock bottom.

It is perhaps interesting to note at this stage the approximate relationship between length, width and cill depth. Length—entrance-width ratio was of the order of 3 to 3.5: 1 length—cill depth ratio roughly 9 : 1.

Effect of Changes in Ship Construction

The development of steam power and its application to marine engineering in the early 18th century saw the introduction of the paddle steamer and the increase in width of midships section was a contributory cause towards the trend of the cross-section back to the rectangular. Improved pumping facilities partially nullified the importance of reducing pumped volume. Dock floors, hitherto had been either mud, natural rock or timber, the latter taking the form of a baulk grillage secured to timber piles, and the earliest departure from these forms resulted in the appearance of the now well-known problem of stabilising the floor against hydrostatic pressure. Nevertheless, with the application of iron and much later steel to ship construction and the consequent increase in the weight of vessels docking, we find that brick and masonry floors anchored to king piles were introduced with success, and later, the more familiar inverted arch made its appearance.

The sequence of progress in ship construction from timber to iron, iron to steel, sail to steam and paddle to screw, all had their influence on the design of dry docking facilities though due to the very slow transition it is a little difficult to trace the trend with accuracy. It is significant, however, that at the time of the displacement of the paddle, around the middle of the 19th century the length-width ratio had risen to roughly 5.5 : 1 and the length-cill depth ratio to something in the region of 15 : 1, although there were instances of this going as high as 20 : 1.

The necessity for crane facilities for handling ship's cargo and equipment also had its influence on cross-section design. In the early stages crane piers were built up from the altars standing out into the dock, and it was not long before we find the line of the cope being brought forward towards the face of the crane piers. In addition to cutting excavation and pumping costs this served to reduce the length of shores for the newer, vertical-sided vessels. The flat-stepped wall face was however still retained in principle and the Sunderland dock section is fairly typical of the period.

The development of railways and dredging equipment further influenced dry dock design. Rail tracks were naturally run as close as possible to vessels in dock to make fullest use of crane-handling capacity and dredging opened up rivers and ports to shipping of deeper draught than hitherto.

So we find a further reduction in the width between copes and increases in cill depth to the extent that in the larger docks at the end of the 19th century length-entrance width ratio reached roughly $9\frac{1}{2}$: 1 and length-cill depth ratio as much as 26 : 1.

In the review of evidence given before the Dominions Royal Commission in 1917 it was established that unit transport costs fell with increased vessel length and proportionate increase in draught, it being pointed out, however, that the conditions of harbours and waterways of the world at that time would not admit the larger vessels necessary to achieve substantial reduction in transport charges.

Recent Construction

It is not surprising therefore that subsequent to this date port access was improved, and much larger dry docks than hitherto were built notably at Tilbury, Liverpool and Southampton and the most recently completed docks at Sydney and Cape Town can safely be said to have been designed to handle the largest vessels, naval and merchant, visualised by those in authority as likely to be constructed during the next twenty years or so. It might here be pointed out that their construction was well advanced before the effect of atomic energy on ship design could be assessed.

These docks are therefore worthy of a few moments' consideration and it is to be noted that the chief new feature common to

*Paper read at the Annual Engineering Conference of the British Association held in Dundee on 28th August, 1947. Reproduced by permission.

[1] Vernon Harcourt Lecture, 1926. Inst.C.E.
[2] De Bélidor. "Architecture Hydraulique."
[3] N. Gould. "Commercial Docks," Rotherhithe.

Development of Dry Docks—continued

both is that the face of the walls have become almost vertical and the altars instead of being formed in the walls themselves are wide and cantilevered out from the face.

The use of cantilever altars may eventually be justified in practice, but it would appear that they must be liable to damage from vessels docking unless protected and will offer obstruction to floating shores, catamarans and rafts during flooding up and pumping down. There are, however, attendant advantages, notably in design where it is more easily possible to keep the resultant pressure back towards the heel of the wall than in the more normal wall with a stepped face.

At Tilbury, where there is only one altar, we find a tendency to abolish the altars by building a large height of the walls with a plain vertical face, relying on hydraulic bilge blocks to replace the more normal shores, whereas at Southampton rigid bilge blocks have been preferred. The variety of present-day ship sections, particularly naval, might demand special arrangements for blocking and shoring but it is not inconceivable that with the tendency to abolish the altar we shall eventually return to the original plain vertical wall with hydraulic bilge blocks. These blocks appear to take up considerable floor area and their use for vessels of varying beam as described by the operative seems a most delicate operation, but in actual practice they are extremely simple to place under water, and most effective, the resultant unrestricted working space between ship's side and dock wall offering considerable advantages.

Electrically-operated shores are in use on one or two floating docks, particularly on the large floating dock at Southampton and no doubt could be applied equally successfully to dry dock construction if the use of shores is preferred.

Two recently-constructed German docks might also be noted here primarily because of their large entrance width and relatively shallow depth over the cill. At Hamburg and Wilhelmshafen entrances are approximately 197-ft. wide and 26 and 29-ft. deep respectively. The length in each case is 1,148-ft. and wall faces are vertical with no shores. The reason for these unusual dimensions is that the docks were designed primarily as ship-building docks where, if necessary, several vessels could be built at the same time and after hull construction had reached a suitable stage could be floated out light to their fitting-out berths. Keel and bilge supports were laid at the commencement of construction, the latter being mechanically operated.

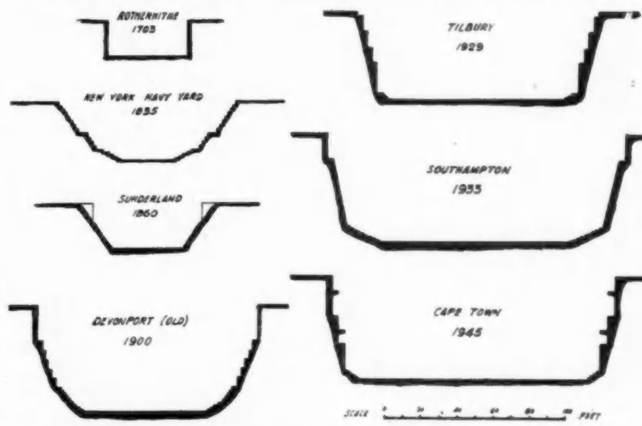
If one discounts these German docks on account of their special design we find in the case of the newest docks that length—entrance ratio has fallen to 8 : 1 and length—cill depth ratio has remained at 26 : 1, and though after reviewing the increases which have taken place during this century it would be unwise to presume that maximum dimensions have been reached, it would nevertheless appear that the depths of navigable channels available in the main ports and canals throughout the world might soon limit substantial increases for some years, unless considerable new and continued maintenance dredging is proceeded with.

On the subject of design, one must agree that the theory of the use of the inverted arch in the floor to resist hydrostatic uplift is perfect sound, but in practice there have been many partial failures. The word " partial " is used because the failure does not represent the collapse of the arch as such, but of the lifting of the upper portion of it due to full water head being in many cases resisted by a completely impervious paving course laid on the main mass of the floor. The floor is designed (a) so that its thickness will contain the necessary arch rise and (b) so that it will distribute the very heavy keel block loads over the substrata. In most instances and particularly in the wider docks the former is the ruling case and a more economical solution would appear to be to achieve firstly keel load distribution and then adequately vent the floor to relieve water pressure. Blocking and inefficiency of floor and wall vents is often pleaded against their adoption, but in any dry dock of average size the small cost of regular maintenance would be insignificant. Venting must, of course, always be considered in conjunction with any available information describing the type and quality of the substratum for it is quite possible that the adoption of floor venting might easily involve the operators in uneconomical pumping commitments to maintain the dock in a dry condition. Further, the effect of drawing a considerable volume of water through the subsoil and with it sand and other fines, may result in settlement problems more serious and expensive than the initial one of putting in a heavy floor.

Entrance Gates

As previously mentioned, timber double-leaf gates were very popular and no less effective during the early stages of dock development, and many are in fact still functioning efficiently in various parts of the country—whether economically or not is another matter. Lock gates were made of cast iron ribs and sheeted with oak planking for the Ellesmere and Chester canal in 1800, and the gates for the dry dock at Montrose were built similarly of cast iron ribs with wrought iron boiler plating about the same time. In 1851 the largest gates which had then been built wholly of wrought iron (excluding heel posts which were of cast iron) were for the dry dock at the New York Navy Yard, each leaf being 36-ft. wide and 30-ft. 8-in. high, for which dock it was also claimed the first all-metal floating caisson was built in the previous year.

It is these two types of closures which have formed the basis of design for dry dock gates up to the present day—the hinged double-leaf gate having gradually fallen out of prominence as the water head to be sustained and entrance width has increased, and because of the expensive work on hollow quoins and other masonry.



The development of dry dock cross-section is indicated by the above diagrams, which are all drawn to the same scale.

Floating caissons have not altered fundamentally in design since that date, though detailing and constructional materials have improved considerably. It is interesting however to note that on the earliest caisson rubber seals were used on keel and stems and proved eminently satisfactory as they are doing at the present day on the recently-built caisson at Cape Town. No cill meeting face has been provided in the German docks mentioned, the caisson being a rectangular steel " floater " sealing at the apron and vertical meeting faces by means of flexible steel plates.

There is little doubt that there can be considerable saving in cost during entrance construction without loss of efficiency if the provision of granite quoins dressed and polished to extremely fine limits as has been the almost universal practice hitherto can be abolished in favour of some combination of flexible seal on the caisson and simple and less exacting detailing of the masonry meeting face itself.

One cannot leave the subject of caissons without reference to sliding caissons so well known and proved. Among the advantages claimed over the floater are that no floating berth is required and entrances can be built with vertical instead of battered sides necessary for floating caisson removal. One other advantage for the slider became evident during the recent war, when it was shown that that type was more stable under bombing when in position than the centre keel floater, although, no doubt, in the case of a very close bomb, both types would be rendered of little service if not armour-plated.

Development of Dry Docks—continued

On the question of constructional materials the most recent introduction has been that of welding and there has been some hesitancy on the part of owners to adopt this method because of the lack of practical experience of the strength of welded joints after immersion in sea water over a period of years. Experimental reinforced concrete floating caissons have recently been built with some measure of success, but do not appear as serious competitors in the field of caisson construction.

Future Progress

Dock engineering is one of the most interesting branches of the profession and in my relatively brief career, it has become abundantly clear that opportunity exists for revising some of the long-standing ideas of what are essential provisions in dry dock works. It had been hoped that it would have been possible to raise for discussion a few of the smaller details of interest connected with the design, construction and operation of dry docks which seem to have been perpetuated simply because they were provided and used successfully in the last dock the particular engineer designed or because the docks operating staff were familiar with particular features for so many years that their omission or amendment in any new structure would compel them to start learning anew.

It can be understood why owners are reluctant to permit an engineer to try out new proposals at his (the owner's) expense and risk, but providing the engineer is himself satisfied of the soundness of his proposals, no doubt a statement of the financial as well as operational advantages would assist in persuading the owner to foresake some of his forefathers ways and proceed along the path of progress.

A call for standardising and co-ordinating the many features of design, construction and operation was made by Mr. M. G. McHaffie, Chief Engineer, Southampton Docks, during a recent discussion at the Institution of Civil Engineers and there is little doubt that an organised exchange and analysis of experience betwee those designing, building and operating the docks would produce an abundance of information and ideas for the common good.

Correspondence

To the Editor of " The Dock and Harbour Authority."

Dear Sir,

War-Time Engineering Problems " Phœnix "

In reply to the letter of Major Hodge which appeared in the October issue of your Journal, I would point out tnat my article which was printed in your August issue dealt not with personalities, but with scientific matters of interest to the engineering profession: matters which, by their publication, had been thrown open to public examination, and indeed, glamourised by the press and radio.

The ability of the team of which Major Hodge was a prominent member is unquestioned; but progress, or conviction, is never attained by the mere utterance of a bland statement. It is not sufficient to say that " the Phœnix was the most versatile caisson ever built." We know it was not. Every floating dock is a challenge to that statement.

Dr. Todd, in two papers, one at the Institution of Naval Architects, and the other at the Institution of Civil Engineers, dealt with the sinking, stability and towing tests. Mr. Cyril Wood, in a comprehensive paper on the Phœnix at the Institution of Civil Engineers set forth in clear terms " the fundamental requirements of the whole undertaking."

Now, I feel sure, Major Hodge will not question their authority on the subject.

Dr. Todd states (p. 12) that the models of the A.1 Phœnix turned over during the sinking tests, and on the Ship Division's recommendation to the War Office, concrete ballast and dwarf brick walls were added to the original design. In other words, as I stated in my article, the original design of A.1 was unstable. It should be borne in mind that the A.1 type was the main unit of the breakwater, the other five types were used in the shore arms and shallows. Taking into account the shape of the unit and the heavy concrete construction, even the small positive metacentric height of 0.92-ft. was a credit to the designers, but the lack of intercostals to break up the large free water surface in the original design was a serious omission, happily corrected by Dr. Todd.

Mr. Wood states that the stipulated freeboard of the A.1 Phœnix was 6-ft. at high water, and the wave height for which it was designed was 8-ft. Now it is firmly established (Sainflou, Brussels Congress, Coen Cagli) that in deep water the reflected wave, or clapotis, will lift its crest, contacting the wall, to a height of $(2h+h_o)$; that is, the full height of the wave plus an amount for the heaping up of the sea above still water level. This means that an 8-ft. wave at high water would over-top the edge of the unit by 4-ft. at least. Then, obviously, a large amount of water would be projected into the open-topped units. At Arromanches, high water stands for three hours.

Consideration of these conditions leads me to ask:

(a) Why was the top of the unit left open?
If it was foreseen that the units would be swamped then,

(b) Why was no provision made to spill the water quickly into the harbour?

Again, if these matters were considered and the risk of shipping water taken,

(c) Why was the unit not suitably reinforced to withstand the consequent stresses?

One of the elementary rules of breakwater maintenance, is to keep water from penetrating the hearting. I trust this was not one of the instances, which Major Hodge italicises, of " knowing what to leave out."

If, as Major Hodge states, the " ideal practical shape " for the unit is a " perfectly rectangular box-like structure " why was it not so constructed?

(d) Were the arguments in 1943 for the 6-ft. wide inset of the outer walls at part height justified?

Mr. Wood states that this inset was " deemed desirable to assist scaffolding " for work afloat. Quite a lot of the work afloat was done without this provision. Surely, a system of projecting ribands on a vertical wall would have served the purpose. Major Hodge, however, says in his letter, that the inset was for the use of the crew whilst voyaging! Neither of these reasons seems to fit in with the serious and sole purpose of the unit, which alone should be the governing factor. Even to claim that this ledge, or gangway, housed the cylindrical anchors and the towing bollards is not valid. Floating docks, which have been despatched to all parts of the world, do not have this provision. I would like to call attention to this latter type of structure: a competent adaptation of the design would have avoided many of the defects of the Phœnix.

The criticism I offered in my article was concerned entirely with the departures from accepted practice of maritime engineering. The experts were committed to their original design, but the modifications they made in the subsequent designs, Phœnix A.X. for sinking in almost peace-time conditions, proves the correctness of my contention. This latter type was not only roofed in, and provided with built-in dwarf walls, but it was provided with a quantity of escape valves in the lee walls, yet the 6-ft. inset was preserved.

Thus it was, in this united professional effort the experts, in their keenness to achieve success within a strictly limited timetable, were swayed by super optimism in a battle with the most relentless element of Nature.

Yours faithfully,

R. R. MINIKIN.

13, Mendip Gardens, Bath.

11th October, 1947.

H.M. Dockyard, Devonport

Widening of No. 10 Dock*

By DONALD HAMISH LITTLE, B.Sc., A.M.I.C.E.

Introduction

H.M. Dockyard, Devonport, was considerably enlarged during the period 1896 to 1906. The work extended into the adjoining district of Keyham and was described in a Paper by Sir Whately Eliot, M.I.C.E.[1] Fig. 1 is taken from that Paper, and it will be noted the extension consisted of four graving docks, one closed basin (No. 5), one tidal basin (No. 4), and about 5,000-ft. of wharf wall. All foundations were carried down to rock, which consisted mostly of shale—usually soft but sometimes very hard—known locally as "shillet." The wharf wall was of monoliths,

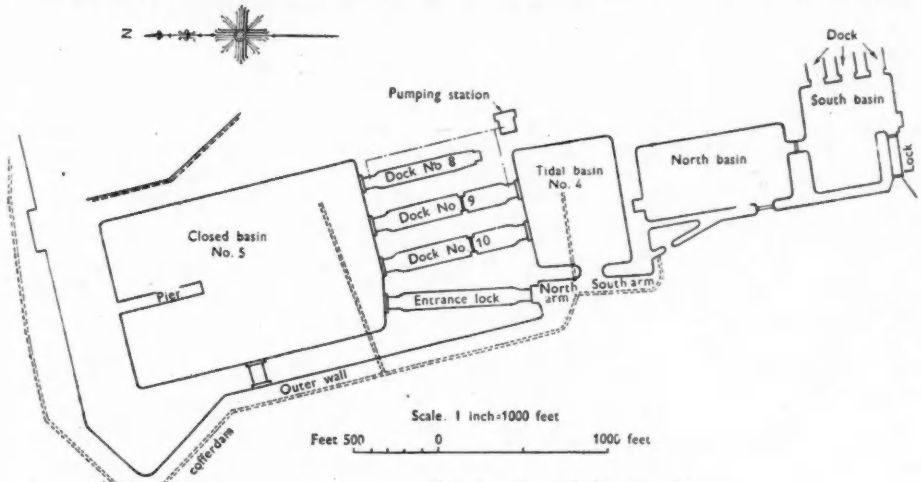


Fig. 1.—General Lay-out Plan.

but the remaining work was carried out in the dry in open excavation behind a coffer-dam, so that it was possible for the rock to be thoroughly well cleaned and covered with cement mortar 2-in. thick immediately prior to concreting. A similar mortar bed was also used at every horizontal joint between subsequent layers of concrete. Special attention is drawn to this because reference will be made to it later.

All the dock and basin entrance walls battered inwards at 1 : 12 and the largest widths at coping were 95-ft. No. 10 Dock (Fig. 2) had a depth from coping to entrance sill of 54-ft. 6-in., equivalent to 47-ft. 2½-in. below mean high water of spring tides and 31-ft. 8½-in. below mean low water of springs. Like two out of the other three docks, it was "double ended," that is, it could be entered from both ends—at the north end from the Closed basin and at the south end from the Tidal basin. The main caissons were sliders—one at each end—but floaters or ship caissons could be used in emergency stops, outside the sliding grooves, at each end and also at an intermediate groove about mid-position of the dock. With the emergency stops in use, the overall length of the dock was 820-ft. Apart from its entrance width, therefore, the dock was quite large, especially in its sill depth of 47-ft. 2½-in. below M.H.W.S. For instance, the corresponding depth of the new graving dock recently completed at Cape Town is 45-ft. 9-in.

Three out of the four graving docks could be filled and emptied from both ends, filling being by independent culverts for each dock and emptying by common drainage culverts leading to one central pumping station.

After the first World War some improvements in docking facilities became essential to deal with increased ship sizes and in 1924 the entrance to No. 5 closed basin was widened to 125-ft. at cope-level, the batter of 1 : 12 being retained.[1]

In 1928 the first proposal for widening No. 10 dock was made; trial pits were dug in 1932; but a final decision to carry out the widening was not reached until 1936. Design work was then put in hand; a contract was placed in May, 1937, and work was completed in May, 1940.

Trial Pits, etc.

Two were dug, each about 6-ft. sq., immediately behind each wall. Summarised details are:

Pit	Depth below cope to: Water level		Soft rock		Hard rock		Pumping rate Maximum: cu. ft. per min.	Minimum: cu. ft. per min.
	ft.	in.	ft.	in.	ft.	in.		
C. (West)	12	7	52	6	60	7	142	8·3
D. (East)	25	7	51	0	54	0	73	6·3

Both pits were dug from September to November, 1932, but work on pit C was always in advance of pit B. Water flowed in somewhat faster after heavy rain and when the dock was flooded, although not very appreciably. The pits were filled in December, 1932, because the water being pumped from them was causing local ground settlements leading to bursts in underground services such as air, water, and gas mains. Sounding-tubes, however, were left in and by May, 1933, the water-level in pit C was 14-ft. below cope and in pit B 21-ft.

A careful survey of the dock floor indicated that it had lifted in places as much as 4-in. Bores were taken into the floor which proved that the top granite stones—2-ft. 3-in. and 1-ft. 9-in. deep in alternate courses—had separated from the concrete. Some fractures of the gutter stones were also noted, indicating that the top granite stones had been acting as an arch with an average thickness of 2-ft. over a span of 74-ft. carrying the weight of vessels in dock. Pressure-gauges were grouted into some of the bores, and pressures corresponding to the water-level in pit C (that is almost M.H.W.N.) were measured in some.

Steel test-piles of the Universal Joist type were driven by compressed air at 80 lbs. per sq. in. with a double-acting Union No. 2 hammer (weight 950 lbs.) along the probable line of the future dam in No. 5 basin. There is no mud overlying the rock bed of this basin and penetrations of 4-5-ft. direct into the rock were obtained under an average of 3,000 blows with a final set of ½-in. for sixty blows. The piles were extracted without much difficulty, the number of blows required ranging from 300 to 800.

Design

Requirements were that the dock entrance was to be widened from 95-ft. at cope to 125-ft.; the barrel at cope from 121-ft. to 151-ft. and at floor from 74-ft. to 103-ft. The south end was to be permanently closed; the central groove was no longer required; at the entrance, a ship or floating caisson was to be used in lieu of the existing slider, and it was to operate into two grooves—not one main groove—and an emergency stop. No deepening of the dock was required, but the lifted portion of the floor had to be re-laid.

When the widening scheme was first proposed it was tentatively assumed that widening would be done on both sides. This would have meant cutting off the faces of both walls to half their widths and adding concrete on the backs for stability. The first major design decision was that widening should be on one side only, involving the complete demolition of one wall and the building of an entirely new one. As a result, the centre-line of the dock does not coincide with that of the entrance—the profiles of the two walls

 Maritime Paper No. 6, presented at the Maritime and Waterways Engineering Division Meeting of the Institution of Civil Engineers on 26th November, 1946, and reproduced by kind permission.

[1] "Keyham Dockyard Extension," Min. Proc. Instn. Civ. Engrs., Vol. clxii (1917-18, Part II), p. 1.

[1] G. S. Jacob. "H.M. Dockyard, Devonport: Widening of No. 5 Basin-Entrance," Min. Proc. Instn. Civ. Engrs., Vol. 229 (1929-30, Part 1), p. 82.

H.M. Dockyard, Devonport—*continued*

now being quite different—but it was the only sound way of carrying out the work.

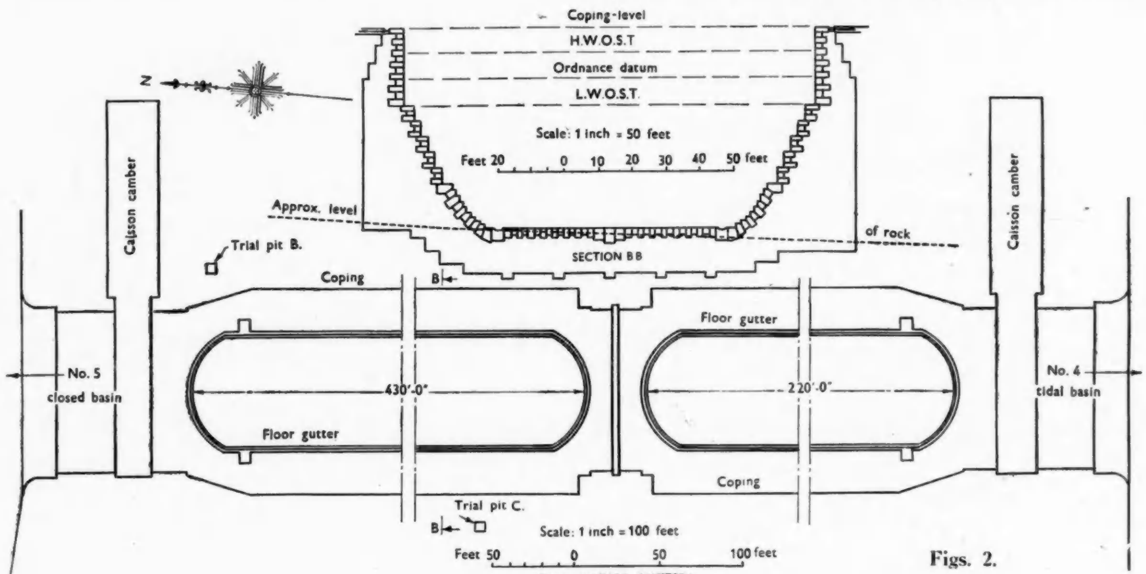
The existing dock floor embodied an " inverted arch " which, on a span of 74-ft., could withstand full hydraulic uplift. Increasing the span of 103-ft. meant that this was no longer possible without considerable strengthening, and it was decided to " vent " the whole floor—existing and extension. Holes were drilled down into the rock and non-return valves, made of rubber balls heavier than water, were fitted into the floor. (Inspection of these valves 6 years after completion indicated that it is very doubtful if their " non-return " properties remain really efficient).

Shipping requirements decided the profile of the new wall and the thickness at cope-level was fixed by the gauge of the 50-ton dockside crane. The back of the wall was designed to suit insets of constructional trench timbering, and the result is as shown in Fig. 3, which illustrates the essence of the main work. By comparison with the existing wall, the new one is somewhat heavy—the weights per lineal foot being 92 tons and 126 tons and the (gravity) resistance moments about the toe 2,000 tons and 2,600 per foot respectively. For normal new construction walls as in Figs. 4 and 5 are to be preferred, but for this particular wall, built in a highly developed area, it was essential to keep subsequent settlement down to the minimum, and in this respect the design was extremely successful. As the trench timber runners were withdrawn concrete was well rammed back into the undisturbed ground.

4 A short length of new wall, embodying a new south penstock, to be completed, including new connection to main South Culvert. The latter required a dam in the main culvert and while this was in the main north culvert had to be kept free.
5 Immediately on completion of item 4, similar work at the north end was to be undertaken.
6 Throughout the contract access across one end of the dock had to be maintained continually for Admiralty personnel and traffic.
7 Within 18 months the following had to be completed:
   (a) 150-ft. of the east wall for the erection of a 50-ton crane.
   (b) 320-ft. of piled crane gantry on the west side for the erection of a 50-ton crane and as a working area for the new caisson contractor.
   (c) All work on the floor of the inner dock, so that the new caisson could be erected there.

Invitation to Tender

In accordance with standard Admiralty practice, tenders were by invitation only and, whilst the Admiralty required to be satisfied as to the sufficiency of temporary works, the full responsibility for these, including design, rested with the contractor. The most important temporary works were: (a) lay-out of working area and



Figs. 2.

In addition to closing that end of the dock, the south end wall had to form a new berth in the Tidal basin and a permanent road and rail route. A width of 30-ft. was the minimum for these purposes and was obviously sufficient on structural grounds.

Order of Procedure

As the work was sited in the centre of the dockyard and all activities had to be maintained, it was necessary to specify the order in which the work was to be carried out; thus:

1 Admiralty to place both caissons in position and pump out dock.
2 Contractor to build, in water, a temporary dam at the north entrance and the south end wall.
3 Admiralty to drain space between south end wall and caisson to test the wall. Contractor to drain space between dam and caisson to test dam. After testing, Admiralty to flood dock, remove both caissons for breaking up on the dock floor, and then de-water dock. Thereafter all pumping to be Contractor's liability.

plant; (b) main dam; (c) shuttering for south end wall; (d) timbering of main trench for new east wall; and (e) dams in main culverts. All contractors had to give an outline of their proposals in their tenders, and it was made clear that details would be required from the successful contractor before final acceptance.

Sixteen firms were invited; thirteen submitted tenders and three had to decline. During the tendering period numerous questions were asked by different contractors. Records of these, and of the answers given, were kept, and two sets were circulated to all contractors—one set three weeks after tenders were invited and the other just before they were due.

It was thought that the shuttering for the south end wall offered good scope for ingenuity but, although one firm proposed a system of climbing shutters, other proposals were simple. The successful tender was the most simple and consisted of panels 4-ft. wide by the full height from sill to mid-tide (about 40-ft.) made up of four whole timbers and faced with metal sheets. Undoubtedly the contractors were correct in keeping to simplicity; finesse is quite out of place on mass concrete work, especially over or in water.

H.M. Dockyard, Devonport—continued

For the main dam, one firm offered a concrete arch 20-ft. thick at the base; another a steel framed arch; but most offered standard gravity coffer-dams of steel sheet-piling, earth filled. Edmund Nuttall, Sons & Co. (London), Ltd., the lowest tenderer, offered a semi-circular concrete arch dam 5-ft. thick composed of an

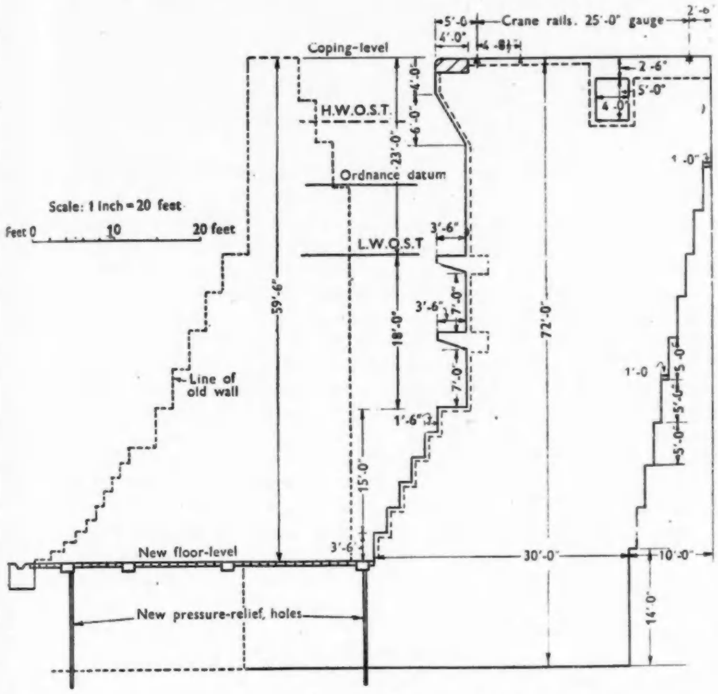


Fig. 3.—Typical cross-section through New and Old Wall, Devonport.

extrados ring of Larssen No. 3 steel sheet-piling and an intrados ring of Universal steel-piling, the intervening space being filled with mass concrete deposited under water. On completion of the dam it was proposed to withdraw the intrados ring of piling and use the steel joists as walings for the main trench "timbering" (Fig. 6).

The proposal was extremely novel but, with parallel sides and unbroken lengths of shuttering, was quite simple to construct, subject to especial care to ensure that an exact semi-circular shape be obtained. It was felt by the Admiralty, however, that the thickness of 5-ft. was not sufficient. Considered as a thin cylinder the average stress in the bottom 1-ft. depth was 350 lbs, per sq. inch and the slenderness ratio of $\frac{\text{thickness}}{\text{length}}$ was 1 : 52. Empirical rules, arising out of experience on permanent arch dam construction, suggest that twice the calculated mean stresses might be expected; that the factor of safety should therefore be 10 instead of 5; and that the slenderness-ratio should not exceed 1 : 75 at the top and 1 : 25 at mid-height. These factors were discussed with Messrs. Nuttall and their proposal to increase the thickness from 5-ft. to 10-ft. was accepted.

Although the dam was part of the temporary works, an item for pricing it was included in the Bill. Increasing the thickness by double obviously nearly doubled the cost of construction, and did double the cost of removal, and the Contractors indicated that they would have to revise their tender price. This they were quite in order in doing; indeed, the main reason for insisting in the form of tender that agreement on such items should be reached before acceptance, was to avoid any subsequent arguments. But it set the contractors something of a problem, because they knew that if they increased their price by too much they might cease to be the lowest tenderer. They managed to avoid doing this, however, and a contract was placed with them, on 28th May, 1937, for completion by day and night shifts in 2½ years.

Plant

Nearly all the plant was new and bought especially for the job—an important feature with regard to reliability and maintenance. The main power, namely, for derricks, concrete mixer, air compressor, and temporary work shops and pumps, was electric. Concrete was mixed in a 1 cub. yd. mixer at a central mixing station and was transported in 2 cub. yd. skips or flat trucks on 4-ft. 8½-in. gauge track with Diesel locomotives. Sand for concrete was brought in by lorry, and coarse aggregate by barge; some excavations were taken to sea by hoppers, and some by lorry to an Admiralty reclamation tip.

Dam

A gantry of timber piles with rock shoes was first built round the outside line of the dam. Most of the pile-driving was done from two derricks, but floating plant had to be used for a short length beyond their reach. This gantry was essential as a stage for accurate setting out of the steel sheet piling; it also carried a pile-driver for use where the derricks could not reach and served as a continuous "dolphin" protection to the completed dam. Driving the steel piles was heavy, but not difficult. Temporary radial diaphragms of sheet piling were used to divide the concreting operation into five sections and holes for subsequent blasting were formed by 2½-in. diameter water tubing, staggered at about 5-ft. centres. Concreting was carried out at a rate of about 1-ft. lifts per hour and one man was employed continuously on gradually raising the tubes as the concrete "went off." This operation had to be very carefully watched, since the tubes were very liable to seize up if left too long.

For the first section a long (15-ft.) steel tube (18-in. diameter), with a bottom-opening flap, was used for placing the concrete. The tube was lifted by a derrick and the opening mechanism was under separate control from the same derrick; that is, the flap could be opened before the tube touched the bottom. A long narrow skip of this nature was necessary in order to get it down

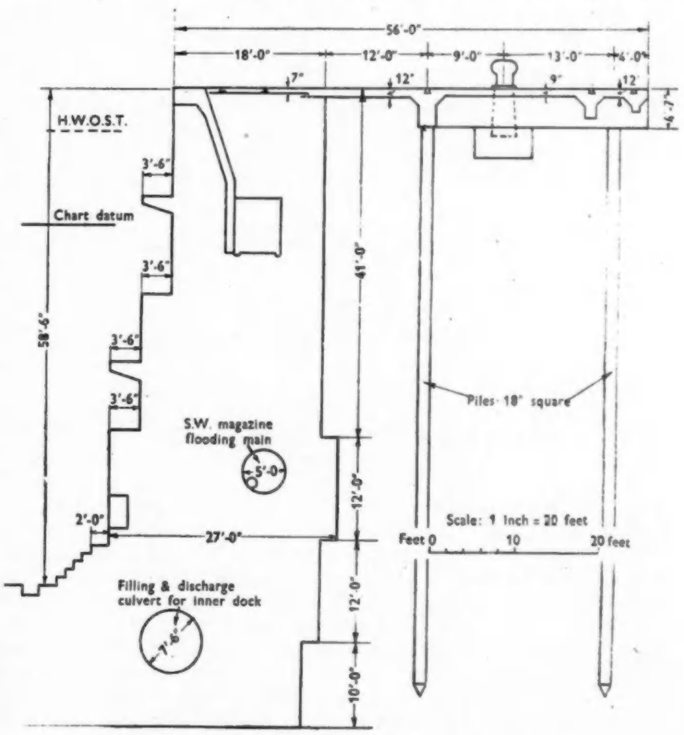


Fig. 4.—Typical cross-section through Dock Wall.

between the somewhat close spacing of the formers for the blasting holes.

When the concrete reached water-level the quantity of laitance was seen to be excessive and a diver's inspection outside the

H.M. Dockyard, Devonport—continued

intrados piling revealed that cement had escaped through the piling so as to cover a large area of the rock bottom of the basin with slurry as much as 2 or 3-ft. deep in places. This loss of cement from the concrete was obviously most serious and for all subsequent concreting a small rectangular timber skip was used, with a trip bottom-opening device that could work only when the skip grounded and took its weight off the derrick. The spacing of the blasting-holes had to be adjusted to suit.

In order to ascertain the quality of the concrete in the first section, attempts were made to drill holes into the full depth of 48-ft. A few were successful, but generally the concrete was so poor that whole stones—the coarse aggregate was 2½-in.—were dragged into the holes and jammed the drills. Pressure grouting with cement was tried, but without success. Accordingly, a test trench, about 12-ft. long by 3-ft. wide, was dug into the dam to a depth of 20-ft. Considering that the trench was surrounded by free water, it was kept dry fairly easily but whilst the concrete appeared better than expected, the contractors decided to add an additional main ring 5-ft. thick over the lower half.

When the dam was eventually tested it proved to be almost completely water-tight, and it remained so throughout the job. At one time, when the old caissons were being floated out, the balancing drain through the dam became choked and the water-level inside was accidentally allowed to rise 1-ft. higher than outside. This "negative pressure" was sufficient to cause all the construction joints to open visibly, but they closed satisfactorily as soon as external pressure came into play.

South End Wall

This was a plain mass concrete wall 30-ft. thick, with an average length of 90-ft. and about 32-ft. deep below M.L.W.S.T. (Figs. 7). No rebate or bonding into the existing work was considered necessary by the Admiralty, although one or two contractors, when tendering, had suggested that there might be leakage without a purposely made check of some kind. The specification called for concreting continuously day and night, so as to avoid under-water construction joints, and the work was actually carried out in six days without the concrete-mixer stopping. Steel skips of 2 cub. yds. capacity were used, with bottom-opening doors operated by an external "skirt" device which could not be released until the full weight of the skip had rested completely on the bottom. It was very successful indeed. The maximum rate of concreting was just over 100 skips per shift of 12 hours, during which time the whole surface was covered once and the level was raised by 3-ft.

In order to ensure keeping the surface as level as possible, a sketch plan of the wall was prepared to foolscap size and the wall was divided into one hundred equal squares numbered consecutively. Site paint marks were made on the existing walls and the shuttering so that the Contractor's "banksman" and an admiralty inspector between them could position quite accurately every skip lowering in accordance with the sketch. Sufficient copies of the sketch were printed to cover each concreting cycle and as a skip was lowered its position was marked off on the sketch. A full inspection of the surface was made by divers daily and local low spots were made up as necessary by diverting skip-loads out of their normal sequence. At no time was it necessary to divert more than one or two skips and the concrete really was "brushed on," as it were, remarkably evenly.

Underwater concreting finished about 3-ft. above low water, which gave a fair chance of cleaning before placing the succeeding concrete. It is, however, difficult to ensure really good workmanship where underwater concrete "breaks surface," and so a vertical construction joint was adopted in the top lift and a front thickness only 10-ft. thick was put in first—such a joint, in effect, had to be formed in any case at the subway. Relieving pipes were also cast in this front wall to keep the rising tide from exerting pressure on green concrete. When this concrete was strong enough, these pipes were plugged and the remainder of the work was carried out completely in the dry behind the front portion, which allowed all the time necessary for thorough cleaning of the surface of the underwater concrete. The latter was very free of laitance, but a certain quantity undoubtedly sank into the "hollows" of each lift in the main body of the wall under water. When this wall was tested it too, like the dam, was almost completely watertight, and within a year even the slight leaks sealed themselves.

On completion, the dock side face of the wall was dried right out and the whole surface (90-ft. by 35-ft.) of the underwater concrete was exposed. This proved to consist of a thin layer up to ⅜-in. thick, of cement paste or laitance. A knife could be pressed into it easily and all of it could have been scraped off readily by hand. It was decided to leave it, however, and in a few months it hardened very slightly. When inspected six years later it was still in the same condition, with a very smooth and even texture as seen from a distance, but actually quite soft. Alternate wetting and drying with sea water from docking operations had had no obvious effect.

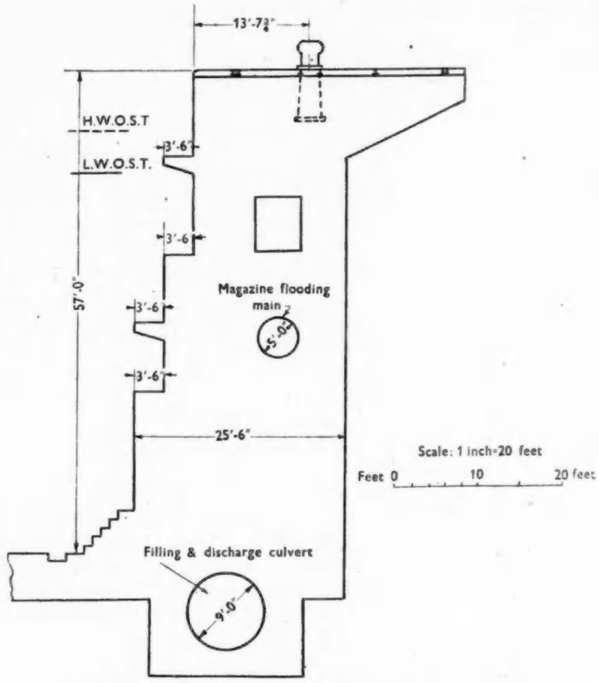


Fig. 5.—Typical cross-section through Dock Wall.

Two large holes, each 3-ft. sq. by 3-ft. deep, had to be cut into the face of the wall to house two large anchor bolts, and the concrete broken out from these proved to be generally good, but with poor patches. The coarse aggregate size was 2½-in. and the concrete mix was equivalent to 3 : 1.8 : 1, except that 10 per cent. extra sand was added for the underwater work.

Excavation

The main new east wall was built in trench immediately behind the existing wall, one side of the trench being strutted off the wall. Rock-level varied from about 40-ft. to 70-ft. below ground level, the depth of the trench being 72-ft. Above the rock, the ground was shillet rock filling, as back-filled behind the old wall when first built. This could be grabbed out with the 1 cub. yd. grabs on the derricks. The rock could be readily drilled and blasted and the fragments shovelled by hand into skips.

Timbering (Fig. 8) was of 9-in. by 3-in. runners, twin 12-in. by 5-in. rolled steel joist walings, and 12-in. by 12-in. struts laced and braced as necessary. The runners were wedged off the walings in the usual way and were always kept a few inches ahead of the excavation. When rock was reached timbering was discontinued and at one place the bottom 35-ft. of the trench was without any support.

Hardly any water was encountered, except for three small springs in the rock itself, which seemed to suggest that the trial pits sunk in 1932 had completely drained the area and the flow into it again through and under the dock and basin walls had not been

H.M. Dockyard, Devonport—*continued*

fast enough to fill it in 5 years. The fact that all the original work had been carried out in the dry had obviously resulted in a first-class junction between rock and concrete. By the time the dam and the south end wall were ready for the dock to be flooded for the removal of the old caisson, some 200 linear feet of trench was in hand—about 100-ft. of it being within 12-ft. of foundation level. Excavation continued with the dock flooded, and again hardly any water leaked into the trench.

Spoil was dumped by the derricks into temporary timber hoppers of about 50 cub. yds. capacity. Lorries ran in under these hoppers and took the spoil to an Admiralty reclamation tip. The maximum rate of excavation was between 2,000 and 3,000 cub. yds. per week.

Cementation

As the floor of the widened dock was to be vented, provision was made in the contract for the rock to be pressure-grouted to serve as a cut-off against water. It was intended to form such a cut-off all along the toe of the old west wall (that is, the one to remain) and in the bottom of the trench for the new wall. Exact details were left to be decided on site. As a first attempt, a series of holes at 9-ft. centres were drilled and thin cement grout was pumped in at a pressure of 50 lb. per sq. in. As this was quite unsuccessful, intermediate holes at 2-ft. centres were made and pressures ranging up to 150 lb. per sq. in. were used. Again it was quite impossible to get any grout in at all, nor even could plain water be pumped in. The rock was not very hard; it was thoroughly laminated and was water-bearing at three places in a length of 700-ft., but it was obviously impossible and unnecessary to grout it.

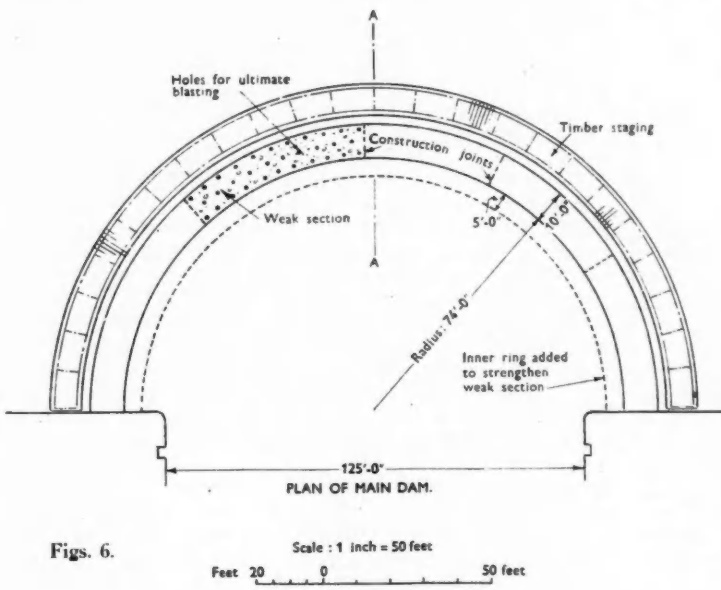
away in the process, but it is not available in large quantities and was used only for reinforced concrete work.

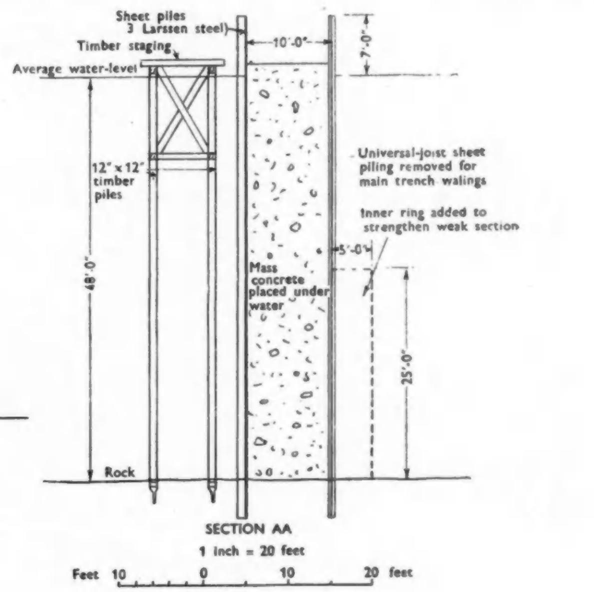
Proportions were specified as so many parts by volume of mixed aggregate to one part of cement, the weight of cement being defined at 90 lbs. per cub. ft. This method of specifying might be satisfactory when aggregate arrives on site ready mixed (for example, Thames ballast), but as the coarse and fine aggregate for this job were delivered separate it was necessary to find the equivalent separate proportions. Tests on early samples indicated that, with the gradings finally adopted, separate volumes of coarse and fine aggregate when mixed together lost one-sixth of their volumes; thus, 15 cub. ft. of stone + 9 cub. ft. of sand become 20 cub. ft. of mixed aggregate. When water and cement were added and the whole was mixed into concrete the reduction was one-fifth; thus 15 cub. ft. of stone + 9 cub. ft. of sand become 19.2 cub. ft. of concrete.

All tests were carried out on dried samples and corrections were made as necessary to suit bulking of the sand as delivered damp. The concrete proportions were as shown in the following Table and although the actual quantity of sand was 60 per cent. of the stone, the (nearest) more usual equivalent mix is shown in brackets:

Position	Mix
Mass concrete in dry	6 : 1 (5 : $2\frac{1}{2}$: 1)
Mass concrete under water	4 : 1 (3 : $1\frac{1}{2}$: 1)
Facing concrete and reinforced concrete	3 : 1 ($2\frac{1}{2}$: $1\frac{1}{4}$: 1)

Exposed surfaces of mass concrete (the face of the new wall, the subway, and the penstock shaft walls) were specified to be





Figs. 6.

Concrete

All coarse aggregate was Blue Elven stone, quarried locally and delivered by barge. This is a very tough, close-grained stone, harder than granite. For mass work the maximum size was $2\frac{1}{2}$-in. and for facing and reinforced concrete $\frac{3}{4}$-in.

Fine aggregate for mass work was obtained from the large china clay by-product dumps on the moors, washed and screened once at works, and then delivered in lorries by road. It contained rather a high proportion—up to 10 per cent.—of china clay flour passing 100 sieve and also a good deal of mica. It was not suitable for high strengths, nor for exposed surfaces subject to heavy attrition (such as roads), but it served very well for mass work in which density, workability, and water-tightness were more important than strength.

Similar sand carried down in rivers from the moors results in a first-class product, all the flour and mica being carried or worn

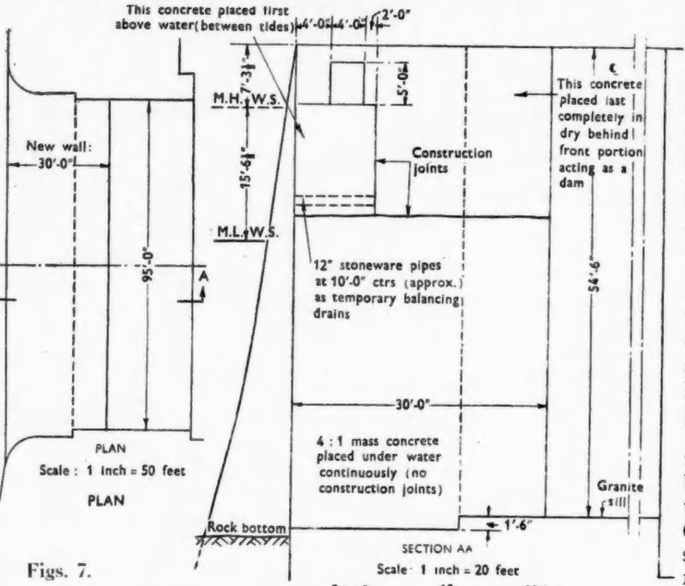
faced with fine concrete 6-in. thick deposited concurrently with the mass work and separated during placing by hand shutters of steel plate. The mass concrete proportion, however, proved to be somewhat rich and trial lengths of wall were built without facing concrete to see what kind of a finish could be obtained. This was so good, so far as appearance was concerned, that facing concrete was omitted for subways, penstock shafts, and stair walls. Facing concrete—involving, as it does, an independent small mixer, special skips, and separating shutters—was a big "nuisance factor" in the main concreting operation and could probably have been omitted altogether.

Extensive grading tests were carried out on coarse and fine aggregates throughout the job and 6-in. test cubes and works cubes were made at the rate of one per day, but usually in groups of two or four. Careful control of water-content was insisted upon; but salt water was used for all mass work, and wear and

H.M. Dockyard, Devonport—continued

tear on the controlling valves was rather high and gave rise to some trouble. Water/cement ratios were 0.35 to 0.55 for 3 : 1 fine concrete and 0.75 to 0.95 for 6 : 1 mass concrete.

Corresponding works cube results at 28 days ranged from 3,500 lb. to 5,000 lb. per sq. in. and 1,500 lb. to 3,000 lb. per sq. in. (average 2,200 lb. per sq. in.) respectively. Strengths for mass work were neither high nor very consistent but, as the calculated design stresses had been kept below 20 tons per sq. ft. (310 lb. per sq. in.), this was not important. The somewhat large variation may have been due to the large size of the aggregate and the relatively large quantities of concrete (2 cub. yds.) deposited at a time—both these items making it difficult to take really representative samples. Indeed, for works cubes and for sieving of sand and stone, sampling was probably the most significant factor and it was unwise to draw too rigid conclusions from the results of the testing. They were, however, an invaluable guide to judgment, except for condemning dirty coarse aggregate. As stated, this was delivered by barge and at times was rather dirty, especially in wet weather when over-burdened was washed



Figs. 7.

into the quarries. Dirt could easily be proved by having a grab full of stone dipped into the basin, when the water around would become of a rich red-brown colour. Invariably, however, test-cubes made of such aggregate were as strong as others; in fact, on one occasion cubes were made of specially selected washed aggregate and of aggregate with 4 per cent. of quarry dirt deliberately added, and the latter proved to be the stronger!

Demolition

As soon as the new wall was sufficiently advanced demolition of the old wall commenced. Blasting was permitted and holes were drilled to the depth of each construction joint—between 3-ft. and 4-ft.—at about 4-ft. centres. Charges of about 2 ozs. were used in each hole and from 15 to 20 holes were blown at one time. Slow-burning time fuses were used to each hole and flying debris was guarded against by large steel torpedo-nets of 4-in. mesh in double layers and well weighted with steel joists; the new wall being protected with whole timbers. A certain amount of breaking up with pneumatic hammers was necessary after each blow, but not very much. The work was set out in terraces so that drilling and blasting and subsequent removal could be carried out concurrently.

When the old wall had been built each construction joint during concreting had been covered with cement mortar ½-in. thick. This did not prevent the blasting occurring at each of these places, but it had undoubtedly help to keep the joints watertight.

Only sufficient explosive for one day's use was kept on the site, daily deliveries being made from the makers' stores outside the town.

Once the demolition had been well started the rate of removal was almost as fast as the earth excavation, the maximum rate being about 2,000 cub. yds. per week.

Masonry

All masonry work was in granite—new stone being used for the water-tight grooves and for sets as top surfacing to the new floor extension, whilst old stone was refixed over the lifted portion of the old floor and for the coping of the new wall.

The new stone came from Cornwall and was fixed and dressed by Cornish masons. Generally for the grooves the stones were 4-ft. by 2-ft. by 3-ft. and weighed 2 tons; but one key stone for the sill arch was 9-ft. by 3-ft. by 4-ft. and weighed nearly 9 tons. They were bolted down into the concrete with 2½-in. diameter bolts 14-ft. 6-in. long—one to each masonry joint. The stones were laid first; then holes were drilled down into the concrete and nearly filled with cement grout and the bolts were dropped in. Water-tight faces were 14-in. deep and ⅜-in. proud for subsequent fine axing down, after fixing, to the specified finish of 0.004-in. Initial fixing was to piano wires and 2-in. cubes of teak, but steel gauges were used for the final "spotting." Dressing was carried out in the usual way, first by hammer and chisel, then by patent axing with axes gradually getting finer and finer, and finally by rubbing with carborundum stone. Checking was done by a steel straight-edge 8-ft. long—proceeding forward in 4-ft. lengths—and feeler gauges. Sill stones were set on steel wedges which were left in and stones up the wall were set on hardwood wedges on the front face which were subsequently removed. Neat cement grout was used throughout, and not mortar beds. Adjoining courses were of different depths so that on the drawing a section appeared to break bond. In actual fact, however, the base concrete could only be laid to the level of the deeper stones and when these were set, making-up concrete was added to form the bed for the shallower stones. There was, therefore, a continuous construction joint at the level of the deeper stones.

When the floor of the dock came to be relaid it was ovbious that those stones, in alternate depths of 2-ft. 3-in. and 1-ft. 9-in., had been laid in the same way, because in most cases the cleavage between stone and concrete was at 2-ft. 3-in. below floor-level, the 6-in. of making-up concrete having come away with the 1-ft. 9-in. stone. Accordingly, no attempt was made at "coursing" the relaid stones and this considerably facilitated the setting. Where the floor had not lifted excessively holes were drilled into the stones and cement grout was pumped in. Before pumping with grout clean water was used, and this drove out the old mortar bed, then disintegrated into a thick milky paste.

The original graite coping to the old wall had been laid in blocks 4-ft. wide by 16-in. deep and up to 4-ft. in length, with slate dowels at each joint, and great care had to be taken in removing those without breaking off the corners. A broken corner meant that the stone had to be dressed back before it could be used again. Payment for this dressing and for other work on old masonry was the only important claim that arose during the final settlement.

Pile-Driving

For the 50-ton crane track on the west side, 19-in. reinforced concrete octagonal piles were used, with heavy rock shoes. Some piles were 75-ft. long and weighed nearly 10 tons. They were driven by a 4-ton semi-automatic hammer through the shillet filling into rock. Driving was very easy in the filling and it was always quite obvious when rock was reached. The set adopted was 1-in. for 10 blows with a drop of 3-ft. As soon as this was achieved twice in succession driving ceased. Over this last portion driving was hard, but it was not carried on excessively and no pile-head was damaged. One pile was test-loaded to 135 tons with a maximum settlement of 3/16-in. and a permanent set of 1/16-in.

Railways

All rails were flat-bottom, 90 lb. per yd., laid on to concrete. Duplex track, consisting of two rails welded on to a continuous base-plate, 14-in. wide by ⅞-in., was used for the 50-ton travelling

H.M. Dockyard, Devonport—continued

cranes and was bolted down into the concrete; 4-ft. 8½-in. gauge single track was held down only by standard spikes grouted in. A flush road surface was provided everywhere by making up concrete laid to camber between rails. Generally, Admiralty experience does not favour welded work for heavy-duty duplex track, but this welding was carried out by departmental welders and has proved quite satisfactory.

Capstans, Valves, etc.

When the dock was built, in 1906, compressed air was adopted as the main power source for capstans, valves, and sliding caisson haulage. This was the subject of some criticism when the Paper on the work was discussed. Nevertheless when the dock was widened, more than 30 years later, all this machinery was in such good condition that it was used again. The valves, which were of the double-gate penstock type with a wet well or shaft, was cleaned up in the shops and the machinery was thoroughly overhauled but, considering the heavy wear and the exposure to salt water that all dock equipment must experience, the condition of all of it was remarkably good.

Responsibility for this work rested with the Admiralty, the main works contractor being required to assist with attendance only.

Removal of Dam

As soon as the new caissons had been satisfactorily tested removal of the main temporary dam was commenced. The external ring of timber staging and the extrados ring of steel sheet piling came away without much difficulty—except that some of the sheet piling required very heavy extracting—and everything was ready for the blasting of the concrete. Holes had been formed for this purpose with 2½-in. tubing, and these were loaded with explosive in canisters about 2-ft. long, spaced out at about 5-ft. centres on instantaneous burning fuse. Each hole was about 48-ft. deep, so that there were nine canisters to a hole, and for a full-depth hole 35 lb. of explosive was used. Firing was by electric exploder (instantaneous) and as a rule only three holes, containing 100 lb. of explosive, were fired at a time. But once, in an attempt to effect a better break-out, five holes, containing 150 lb., were fired at once. None of this firing, in which the main energy was expended in breaking up the concrete from well-defined holes inside it, did any harm to the adjoining permanent walls.

The removal proved very troublesome, however, because the concrete, having been placed under water, was very "patchy," with pockets and horizontal bands of weak concrete, which caused the dam to break off in large irregular sections rather than small pieces and straight cleavage planes from top to bottom, as had been hoped. The large sections, up to 15-ft. by 10-ft. by 12-ft., had to be broken up on the bottom of the basin in sizes that could be picked up by the bucket dredger or slung from the 10-ton derrick cranes. At first the drilling of fresh blasting-holes by divers was tried, but this had to be abandoned because the drills jammed too frequently, and ultimately all the breaking up was done by "plaster" charges simply laid on to the concrete. The largest weight of explosive fired this way at one time was 15 lb., but as so much of this energy was expended freely in the water it proved to have too much effect on the permanent work and subsequent charges were limited to 10 lb. Before the dam could be completely removed it became necessary to dry-dock a warship in the dock, and sufficient of the central part of the dam was cleared to allow a passage across it. The final blasting and dredging, therefore, was actually done with the dock dry and a ship in it.

Costs

The estimated cost of the widening work was £400,000. During the contract it was decided to close the south end of No. 9 dock and form a fitting-out berth along the north wall of No. 4 tidal basin, at an estimated cost of £40,000. This work was added to the main dock widening contract and the final settlement for this was just over £400,000. Departmental work on fendering, railways, roads, water mains, etc., amounted to £30,000.

Acknowledgments

Messrs. Nuttall were represented on site throughout by Mr. J. A. L. Hooper, B.Sc., and the Author wishes to acknowledge the very pleasant spirit in which the work was carried out. It could so very easily have been quite the opposite, because the site was in the heart of an important dockyard, the activities of which had to be maintained. Interruptions by ship movements in the basins at each end of the dock were inevitable; at one time two aircraft carriers were docked in the adjacent dry docks less than 200-ft.

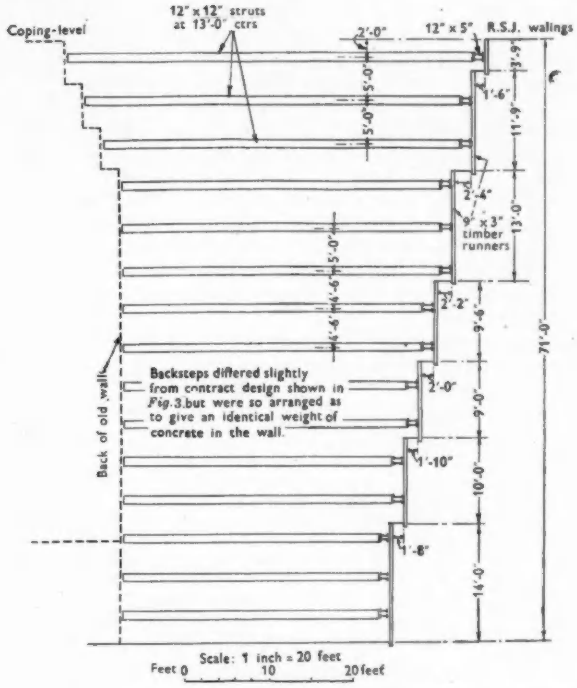


Fig. 8.—Trench Timbering.

away; dockyard traffic—trains, lorries, cranes, and personnel—crossed the contractors; and the main pumping system was common to all dry docks—No. 10 included. To offset this, however, facilities existed in the dockyard for carrying out major plant repairs of almost any kind and, as the Contractors were always reasonable in their dealings with all Admiralty departments, these facilities were readily made available to them. They were not cheap, because Admiralty charges to "private individuals" are purposely high so as not to encourage them, but at times their promptness was invaluable.

In short, the Contractors became almost another department in the dockyard and entered into its "give and take" life, to the mutual benefit of everyone. Apart from a delay in the completion of the caisson by another contractor, the work was completed on time; no arguments over interruptions arose; and at the final settlement the value of disputed items was less than £2,000.

(To be continued)

Panama Canal Traffic.

According to figures recently released by the Canal Authorities, a total of 4,260 ocean-going ships passed through the Panama Canal in the 1947 fiscal year to June 30th last, paying tolls of $17,596,602. This compares with 5,903 vessels, paying tolls of $23,661,021, in the year 1938-1939. Cargo passing through the Canal totalled 21,670,518 tons, and although this was the best figure for five years, it was still 22 per cent. less than the 1938-1939 figure. Cargo moving through the Canal to European ports was much less in 1946-1947 than in 1938-1939, although the amount moving from the Canadian Pacific coast and Australasia was slightly higher. Cargo from Europe going to Australia and the West Coast of South America was less than half the amount in 1938-1939. Shipments from the United States to the West Coast of South America totalled 774,499 tons last year, or about four times the 1939 total.

Review

Scale Models in Hydraulic Engineering. Professor Jack Allen. Longmans, Green & Co., London, 1947; 407 pp., 35 plates and 137 figures, 30/-.

Although the principles of dynamic similarity in hydraulics were published by that master of applied science, Sir Isaac Newton, in the seventeenth century (*Principia*, Book II, Prop. XXXII, Theorem XXVI) and much valuable matter was published by Froude and Osborne Reynolds in the nineteenth century, this is probably the first text book on working hydraulic models which has been produced in English. Incidentally it will also be of much value to hydraulic engineers as a guide to general principles.

The author, who co-operated with Professor A. H. Gibson at Manchester for many years and took a large part in the development, operation and interpretation of the Severn River models, is a spiritual descendant of Osborne Reynolds, whose masterly work in the 'eighties first placed the use of hydraulic models of estuaries on a practical basis. British work in this field has specialised in tidal estuary models to a rather greater extent than has been the case in other countries, although very good work has been done on tidal problems by Thijsse at Delft, Lueders at Wilhelmshafen and the U.S. Engineering Department at Vicksburg. Non-tidal rivers have been much studied in India, as well as in Continental and American laboratories.

This handsomely produced volume will be very welcome to all those engineers and harbour authorities who wish to familiarise themselves with the principles and technique of models.

The Author has endeavoured to cover the whole field of hydraulic models, but shows a natural bias towards tidal problems and most of his readers will find that other matters dealt with are subordinated to tidal ones. He commences with the fundamental problems of dimensions and "similarity" and then passes to actual models, firstly of water control devices (weirs, etc.), secondly, obstacles in waterways, thirdly, non-tidal rivers and fourthly, tidal rivers. Silt and salinity are next dealt with and four large tidal models are discussed in detail.

The question of scales is then specially studied and next the mechanisms for producing tides. Brief accounts of foreign laboratories are then given, followed by a description of the Author's experiments on the stability in streams of blockwork, rubble and sand, some remarks on wave action, apparatus for measuring depths and velocities in models and finally experiments on filters and dams.

Quite naturally the subject of scales for models is given a special chapter. It is one of fundamental importance since unless the right scales are chosen, the model will not behave like its prototype. In most estuaries the dimensions are so great that unless the horizontal scale (1 in x) is small, the model becomes inconveniently large and yet unless the vertical scale (1 in y) is fairly coarse the velocity of the water in the model will be so small that the flow will not be "turbulent" and this is essential. In actual fact, except for relatively short rigid objects, such as sluices, the vertical scale must be much coarser than the horizontal scale and rather paradoxically this is what happens in nature where dimensions are reduced. Gerald Lacey in relation to rivers and canals has put forward strong arguments for a crucial value $y = x^{\frac{2}{3}}$ or, what is the same thing, an exaggeration of slopes ("distortion") in a model $x/y = \sqrt{y} = \sqrt[3]{x}$. This almost approaches a "law" in its generality for channels with loose beds.

This may be shown in a rather interesting way by considering a specific catchment area which feeds a river channel having a specific cross sectional area. In a model of the same to a horizontal scale of 1 in x, and a vertical scale of 1 in y, with constant run off per second per unit area of catchment, the discharge per second is reduced in the model by a ratio $1/x^2$. In the channel the cross sectional area is reduced in a ratio $1/xy$, so that the velocity (discharge divided by cross sectional area) must be reduced in the model by the ratio $xy/x^2 = y/x$. The Newton-Froude "similarity" condition states, however, that the velocity in a model for gravity-produced motions to be similar, should be reduced in the ratio $1/\sqrt{y}$, so that we have $y/x = 1/\sqrt{y}$, or $x/y = \sqrt{y}$.

A similar result can be obtained for tidal models by assuming h/t is constant for prototype and model where h is the tidal rise or range and t is the periodic time.

In order that the laws of resistance shall be conformed to, there are some further conditions relating to the nature of the bed of the channel and its size, but in fortunate fact, owing to the relatively greater unit resistance in small channels and providing the material is not coherent, this is compatible (within limits) with the use of almost the *same* bed material in the model as in the prototype. The sizes of the grains in relation to the depth and to the thickness of the layer of non-turbulent water on the bed are the criteria. Distortion tends to reduce the ratio of the friction to the gravity forces but for the stated value the increased unit friction compensates. For large distortions, the friction is inadequate and the bed must be coarser than that of the prototype.

As Lacey has further shown this specific value of the distortion means that the *vertical* velocity of the water in the model is much the same as in the prototype. The vertical velocity is the horizontal velocity multiplied by the slope, i.e., the vertical velocity in the model is $x/y\sqrt{y}$ that in the prototype and if $x/y = \sqrt{y}$ this is an identity.

Prof. Allen rarely mentions by name the "Froude number" or the Buckingham criterion for the solution of dimensional equations, but all the ideas are there. He also does not give much about terminal velocities for the fall of particles in water, the departures from Stokes' law for such particles or the several varieties of turbulent flow. His references to Reynolds so-called criterion of exaggeration of slope (h^3e) could well have been omitted since this rule appears to be of little or no value and Reynolds' argument for it does not seem cogent. Practice does not confirm it and the real criterion is the development of turbulence in the model. The Author's own proposal seems much preferable.

In discussing the density of bulked silt (p. 235) he makes no mention of Terzaghi's pore co-efficient method which enables all such questions to be stated clearly in terms of the "void" to "solid mineral" ratio.

On p. 312 he refers to some recent model work in China but does not mention the much earlier model of Heidenstam and Chatley of 1917, which indirectly led to the control of the Yangtze Bar in 1936.

The Author does not sufficiently discuss the effects of distortion in changing the perimeter/width ratio of channels; in extreme cases this may double the rubbing area.

Something more might have been said as to the time scale of scour and silting, which certainly needs further study. The time scale of scour in particular raises several serious problems and the behaviour of coherent materials requires much more investigation.

In his discussion of the stability of flexible bolsters (rubble in cages) not sufficient emphasis is placed on the flexibility. If this is great the stability of banks built up with such bolsters is very high indeed and it seems probable that in his experiments the model bolsters were still too stiff.

In respect to tidal mechanisms no mention is made of the hydraulic piston method of operation which has been successfully developed by the National Physical Laboratory for certain tidal models. This system is less cumbrous than the gear or link driven plunger system.

In the chapter on wave action some reference could well have been made to the work being done by the Beach Erosion Board (U.S. Corps of Engineers, Washington), which is of great value. The Naval Meteorological Branch of the Hydrographic Department of the (British) Admiralty has also done some very useful work on waves during the war but not much has been published about this. The new Hydraulics Research Organisation, directed by Sir Claude Inglis, should also be noted.

Completeness in such a subject would be a practicable impossibility and it only remains to express a very high appreciation of the book and the hope that its popularity will be such that a second and enlarged edition will rapidly be called for.

HERBERT CHATLEY.

Notes of the Month

Tugs for Italian Ports.

It is reported that the United States has ceded to Italy nine ocean-going tugs belonging to the American services at Hamburg. The transfer will take place under agreements for giving United States war surpluses to Italy.

Traffic at the Port of Liverpool.

Figures for the Port of Liverpool for August, as supplied by the Mersey Docks and Harbour Board, show a decline on both the import and export sides as compared with the previous month. The total of goods discharged was 691,044 tons compared with 711,366, and 206,948 tons were exported as against 238,893 in July.

Port of Bristol Statistics.

A substantial increase in the tonnage of shipping using the Port of Bristol is reported for the six months ended September 30th, 1947. Foreign vessels entered numbered 371, of 1,126,920 net registered tons, the corresponding statistics for the same six months of 1946 being 284, and 880,300. Coastwise shipping similarly rose from 4,281 to 4,876 ships, and tonnage from 537,396 to 636,313.

Corinth Canal to be Repaired.

It was recently announced that an agreement between the Greek Government and the U.S. aid-to-Greece mission for the execution of work needed to re-open the Corinth canal between the Greek mainland and the Peloponnesus has been signed in Athens. The agreement also provides for the repair of railway and port installations in the Piræus, Salonika and Volo.

Extensions at the Port of Kolding.

Plans for extensions at the Port of Kolding have been submitted to the Danish Government by the local council and harbour board. It is proposed to lengthen the North Quay by 140 metres and to construct a new quay 160 metres in length, and having a depth of 6 metres of water alongside, while a pier with tanker berths is also to be constructed. It is estimated that the work will cost 3,600,000 k. and will take at least three years to complete.

The Problem of Siltation at the Port of London.

The Port of London Authority has decided to carry out a comprehensive investigation into the problem of silting in the River and Docks, with a view, if practicable, of introducing remedial measures and thereby reducing to a minimum the recurring expenditure on dredging operations. A special Department comprising officers with expert knowledge of the various aspects of the problem has been set up and the assistance of the Department of Scientific and Industrial Research has been invoked.

The Port of Mikindani.

The area situated in Mikindani Bay, in the Southern Province of Tanganyika and hitherto known as Mto Mtwara, which, as announced in the May, 1947 issue of this Journal, has been selected as the site for a port for shipping groundnuts, will in future be known as Mikindani. The existing township of that name will now be known as Old Mikindani. The actual lagoon on which the port will be built will continue to be known as Mto Mtwara, as shown on Admiralty Charts.

Hudson Bay Route.

Commenting on the present shipping season via Hudson Bay, the "Winnipeg Free Press" reports that most of the ships will once again arrive in ballast, and this remains the greatest problem for the Hudson Bay route to overcome. "There can be no question," states the paper, "that with the wider use of Gyro-compasses, radar, ice-breakers, and other modern aids to navigation in Hudson Strait, the season for the route can be materially lengthened. This will mean a potential expansion of east-bound traffic. But unless the outgoing and incoming cargoes can be brought much more into balance than they are to-day, the Hudson Bay route cannot serve to the full the purpose for which it was designed."

Danube Transport Hampered.

Transport on the upper Danube has become almost impossible because of the low level of the water caused by prolonged drought. The already over-burdened railway system with limited rolling stock is unable to cope with the demand.

Wagon Shortage Delaying Discharge of Cargoes.

The wagon shortage is causing delay in the discharge of iron ore and timber at North-East Coast ports. Because of this, discharging facilities for iron ore at Tyne Dock cannot be utilised to the full, and the dispatch of ore to Consett is being retarded at The Hartlepools and elsewhere. Timber discharge is also lagging behind capacity.

Port of Spain Cargo-Handling Problems.

A joint committee of the Chamber of Commerce and the Shipping Association which has been investigating the receipt, storage and delivery of cargo at the Port of Spain, Trinidad, has now recommended the establishment of a public utility corporation to manage the wharves and warehouses in the interest of efficiency and flexibility.

Floating Dock for Athens.

A floating dry dock of 10,000 tons lifting capacity was recently towed to the Port of Piraeus. The arrival of this dock which was constructed in Germany about 30 years ago and has been allocated to Greece as war reparations from Germany, will enable many vessels which previously were obliged to proceed to Alexandria or Italy for dry-docking or bottom repairs, to carry out these operations in Piraeus.

New Waterway in Gold Coast.

Plans to make a 300-mile waterway to bring bauxite from the interior of the Gold Coast have been announced by the West African Aluminium, Ltd. It is proposed to construct a dam near Ajena, nine miles north of Sencni, thus forming a sheet of water up to Kete Krachi in the north. To make the Volta navigable to the new dam, the Kpong rapids are to be by-passed, and the Senchi rapids removed so that the river will be navigable from Kete Krachi to the sea.

Loud Speaker Control at Welsh Ports.

Loud speakers are to be used by the G.W.R. at Cardiff and Swansea Docks to hail tugs and control the berthing of vessels. At Cardiff five loud speakers, operated from microphones at three vantage points, will cover Queen Alexandra Dock, Roath Dock and Roath Basin, while at Swansea one swivelling loud speaker at the sea lock will be audible throughout King's Dock and in the communication channels leading from the Queen's and Prince of Wales Docks.

Northern Ireland Fishing Harbours.

A report on the survey of fishing harbours, undertaken on behalf of the Government of Northern Ireland, has been presented to the Minister of Commerce, and decisions on the recommendations contained in it are expected to be made shortly. The survey has been carried out by Mr. James Boyd Brodie, M.Inst.C.E., who has had considerable experience of fishing harbours in Scotland. His report has special reference to the exposed north coast of Co. Antrim, where there is an urgent need for improvements in the harbours.

Improved Conditions at the Port of Czezecin, Poland.

Following completion of the work connected with the raising or removing of wrecks, which until now, have obstructed the free movement of vessels in the port area, the conditions for navigation in the Port of Czezecin have been greatly improved. The sounding of some water areas in the proximity of the quays has also been finished. During August last, a total of 142 ships were cleared, representing the flags of eight countries. The trade handled at the port totalled 105,114 tons, the principal imports being iron-ore, scrap paper, wood pulp, general cargo and horses. The chief export was coal.

PORT OPERATION

Part Eleven of a Series of articles by A. H. J. BOWN, M.Inst.T., A.C.I.S.
and Lt.-Col. C. A. DOVE, M.B.E., M.Inst.T.

(Continued from page 154)

Part 5 (B) : Cargo Handling—Method

All cargo-handling operations in the port area may be classified according to whether they are part of the process of (a) loading or (b) discharging ships. An exception is provided at those ports which offer warehouse accommodation for commodities produced in their own hinterlands which may be destined ultimately for home consumption.

The principles governing many of the operations, e.g., piling and unpiling, slinging cargo and rigging gear, are the same irrespective of the object of the work.

Before a ship can be loaded, except for its maiden voyage or following repairs, it is normally necessary to discharge her first. It could be argued, therefore, that logically discharging should be discussed before loading, but in order to assist students in following clearly the more difficult processes of loading, on which the relatively simpler job of discharging so frequently depends, loading will be discussed first.

Before proceeding further it should be understood by the student that the purpose of this chapter is to deal with the practical aspects of the subject without going too deeply into documents and documentation which will be dealt with separately. Documents will only be referred to where it would be helpful in order to clarify what has been written.

Allocation of Berth and Opening for Exports

The first step in a loading operation is taken by the Shipping Company when they apply to the Port Undertaking or Dock or Wharf Owners, as the case may be, for a berth at which to load the ship. The Port Undertaking then " allocate " a berth, after which they agree a date with the Shipping Company on which the quay and transit shed or area serving the berth may " open for exports." This date may be anything from 3 days to a week or more before the day on which the actual loading to ship will commence. During the interim period the ship may, of course, be discharging at another berth, refitting, undergoing repairs, etc. Ideally, the period allowed for opening for exports should be (a) long enough to allow the shore operators to accumulate sufficient cargo in the transit shed or area to give the ship a good start and thus enable loading to progress, once it has commenced, without delays being caused by waiting for cargo to arrive and (b) short enough (1) to avoid wasting shed space by filling the transit shed or area with cargo, several days before the ship is due to commence loading, (2) to keep the striking gangs fully occupied.

Shipping companies try to arrange the opening for exports date well in advance to enable them to give shippers as much notice as possible. This they do in normal times by sending advice cards to regular or likely shippers and by newspaper advertisements.

Accommodation Berths

Many Shipping Lines have regular berths, known as " accommodation berths," and fixed sailing dates, which do not require the voyage to voyage arrangements described above but are the subject of long-term agreements with Port Undertakings.

Long before the opening date for exports the Shipping Company have been booking space in the ship for Shippers. Some of this tonnage comes from the publicity described above given to the sailing, and some results from the direct approach of the Shipping Companies' representatives to the Shippers.

Engagement List

From the demands for shipping space an " engagement list " is prepared. This document sets out in detail particulars of all the cargo booked. It shows for each package or consignment; marks and numbers, external measurements, cubic measurements, weight and special characteristics, e.g., frail or hazardous nature, low flashpoint, special stowage requirements and high value. It also states, where known, the method of despatch, i.e., road, rail or water and when due to arrive.

The engagement list, particularly when the ship is fully booked, is of great value to all the operators at the loading berth. It can act as a guide to the Cargo Superintendent as to the best way of berthing the ship, i.e., starboard or port side to the quay. Often when the ships are fitted with their heavy derricks on one side only, it is necessary to know whether the lifts they are to make will arrive by land or water conveyance so that the vessel may be berthed accordingly. Sometimes both means of transport are to be used and the matter is of small consequence, but often the double handling of heavy cargo, which is expensive, can be avoided by attention to this particular detail. The heavy derricks referred to here should not be confused with " jumbo derricks," which can be rigged to work to either side of the ship.

Mixed cargo of small consignments awaiting export. High piling of some consignments due to shortage of floor space. Note no cases stowed on corners or edges, all barrels and kegs stowed "bung-up."

From the engagement list the Cargo Superintendent can prepare a draft stowage plan. Such a plan can rarely be strictly adhered to as loading proceeds, particularly if the Master or Chief Officer of the vessel is not available when it is being prepared, nevertheless, together with the engagement list it can be of great value to the shore staff, both during the period when cargo is being received for export and later when the ship is loading.

The engagement list should give the clue as to which cargo is to be stacked in the trasit shed or area before being loaded and which should be loaded into the ship direct from land or water conveyance.

Planning the Transit Shed

The stowage plan should enable the quay staff to plan to stack the cargo on the transit shed or area in the most suitable places for loading. Cargo should be stacked in the area opposite the position which will be taken by the hold into which it is to be loaded when the ship comes alongside. Cargo for bottom stowage should be placed near the front of the transit shed. Where the quay apron is wide enough, cargo which is not likely to be pilfered and will not deteriorate through exposure to the weather, may be stacked on the quay apron provided it will not cause delay and congestion by fouling the quay lines or pitches or by impeding the progress of road transport and the work of the shore gangs.

The careful planning of the stacks of cargo in the transit shed or area can prevent much avoidable movement of cargo, cut

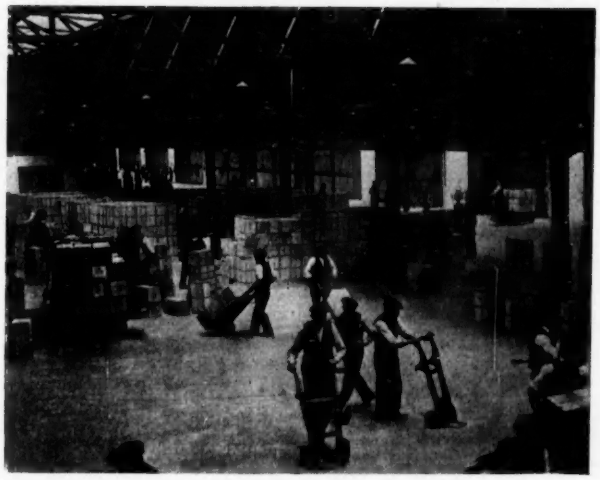
Port Operation—continued

down unnecessary work and reduce congestion by (1) reducing the distances the cargo has to be moved from stack to ship, (2) eliminating cross leads. An example of cross leads would be caused by stacking cargo intended for stowing in No. 5 hold, in a space in the transit shed opposite No. 1 hold and cargo for No. 1 opposite No. 4, (3) increasing the use of mobile plant by reducing the length of carry, (4) increasing the use of roller runway, which cannot be used where it crosses pathways required for the movement of other cargo.

Direct Loading

Direct loading takes place when cargo is hoisted direct on to the ship from the land or water conveyance which brings it to the loading berth.

In the case of loading from land conveyance, i.e., railway wagon or road vehicle, it is used for (a) heavy lifts, i.e., lifts which are too heavy for the quay cranes or where there are no quay cranes, too heavy to be man-handled, (b) bulky and delicate packages which would run the risk of damage by too much double handling, (c) highly pilferable cargo, e.g., spirits, when suitable lock-up accommodation in the transit area is not available, (d) hazardous cargo for deck stowage, (e) bulk cargoes, e.g., coal or ore, provided there are sufficient loaded wagons available to keep the ship going without delays and sufficient quay line rail tracks on which to place the number of wagons necessary to keep the ship going. For certain types of plant, e.g., coal hoists, direct loading is an automatic operation, (f) a good run of cargo which is easily handled and checked, e.g., bags of flour in similar conditions as those prescribed under (e).



Homogeneous cargo being received into transit shed for export. Compare height of stacks with man (no high piling). Note carefully piled stacks.

Generally speaking direct loading from land conveyance militates against quick turn-round of ships, road and rail transport. Experience shows that for general cargo working the saving in double handling costs, the reduction in pilferage and lessening in damage which are claimed for direct delivery, are more than offset by the saving in the time of ships, motor transport, railway wagons and the avoidance of congestion. There are, of course, important exceptions such as the loading of bullion, and occasions when necessity dictates the means to be used, e.g., heavy lifts and late arrivals, but as a general rule direct loading from shore is to be avoided.

The same considerations do not apply to loading from craft. Loading from craft takes place in two sets of circumstances, (1) when the ship is moored out in the stream, when loading from either side of her must necessarily take place from craft (overside), (2) when the ship is moored alongside a berth in which case overside loading can take place from one side of the ship at the same time as she is being loaded from shore. Since overside loading must obviously take place from some sort of craft, it is desirable to load direct from the original craft where possible. Overside loading can be very wasteful of craft unless the timing of the arrival of the craft is carefully calculated. It is frequently necessary of course to discharge craft to shore before loading either because of its early arrival, or to inspect it, or to divide it up to various ships.

Arrival of Cargo in the Port Area

Cargo for loading arrives by rail, road or water. The arrangements for despatching the cargo for shipment to the port area are made by the shippers or consignors.

Rail

Advice of the forwarding of cargo by rail to the port is sent to the port undertaking by the shippers or consignors. By this means the port undertaking is informed before the arrival of the railway wagons at the exchange sidings of such relevant information as wagon numbers, contents and ship.

This information enables the dock railway staff after the wagons have arrived in the exchange sidings to sort them to the various berths or warehouses at which they are required.

Yard State

In most ports it is the practice for the railway staff to issue a statement to the quay staff setting out particulars of wagons which have arrived. This document is sometimes known as a yard state. The quay staff's duty is to advise the yard staff of when and where they require these wagons to be placed, e.g., wagon No. 12345, Berth No. 3, No. 1 platform line, door No. 3, 1st shunt 10th October, 1947; wagon No. 67890, Berth No. 2, No. 2 quay line, opposite No. 2 hatch, 2nd shunt 6th October, 1947. The rapid and accurate exchange of information between the two staffs is of the greatest importance in ensuring the quickest possible turn-round of wagons and correct first-time placing, thereby eliminating (a) unnecessary movement of wagons in the transit area and (b) unnecessary long carries of cargo by striking gangs. In some ports the desired standard of liaison is produced by having a member of the quay staff stationed in the yard, in others a system is in force whereby a member of the quay staff chalks the berth placing required on the side of each wagon, whilst it is standing waiting to be sorted.

Call Forward

The timing of the call forward of wagons from the yard to the berth and the number called forward for each shunt are two factors which play a prominent part in producing good dock railway working results.

The drawing off of empty wagons which have been struck and the placing of loaded wagons should be timed to take place when other loading operations are not being performed on the quay or in the transit area, i.e., at meal time breaks and between shifts, or in countries where ship working only proceeds in daylight hours, during hours of darkness. Experience has shown that the best results, both in dock railway and quayside operating, are obtained when shunting takes place at regular fixed times each day.

Sound judgment must be shown by the quay staff in ensuring that wagons called forward can be completely discharged in the time allowed. Where, however, an error of judgment or some unforeseen contingency, e.g., bad weather or power failure results in a wagon or wagons not being unloaded before the next shunt is due to take place, then the completely or partly undischarged wagons should be drawn off with the empties and not placed again until the next shunt but one. Only in cases of dire necessity should this rule be broken, for its observance is an important factor in reducing unnecessary shunting engine time and railway wagon congestion, and in permitting the dock railway staff to plan their work. Where the quay staff are in doubt as to the number of wagons which can be off-loaded between shunts, they should err on the light side in calling forward, even though it may result in a little idle time for the dock labour. A permanent well-trained quay staff will, however, know their berth and labour well enough in normal circumstances to avoid this.

Port Operation—continued

An important characteristic of rail-borne traffic from a quay operator's point of view when loading ships, is that it can be held in the standing sidings and called forward on to the berth as required. This ability to programme cargo forward is essential to rapid loading.

In noting this point the student should not lose sight of the importance of turning railway wagons round quickly and not using them as warehouses. The export quay staff should also remember that by discharging loaded wagons they are " making empties " for the import quays.

Road Transport

Road transport from a port operating point of view is much more difficult to control than rail traffic and often presents one of the main obstacles to rapid ship loading.

This characteristic arises from the practice of shippers and consignors of forwarding cargo as and when it suits them after the day for opening for exports has been announced, without regard to when it is required for loading, e.g., cargo required for 'tween deck stowage might arrive on the first day of opening for exports, regardless of the fact that it will not be required for loading to ship for 10 days or more and will in consequence lie about the transit shed, taking up space required for bottom stowage cargo and risking the possibility of deterioration, damage and pilferage. On the other hand, cargo required for bottom stowage might not arrive till several days after the ship has started. The above criticism refers mainly to short-distance traffic. Long-distance traffic is usually well advised, as are also valuable cargoes, hazardous cargoes, heavy lifts and cargo for direct loading.

Experience shows, however, particularly at berths where similar cargoes are handled regularly, that the quay staff are usually able to judge which will be their busy days and man their unloading points for road transport accordingly.

Sometimes, for unforeseen and often inexplicable reasons, the road traffic expected does not arrive, and the labour, where it cannot be suitably moved to other jobs, stands idle. More often, however, lorries pour down to the berth during the first hour or two after work commences and are dealt with in order of arrival. The result is that the later ones are kept waiting hours for their turn to be off-loaded, which, when it comes, may only take a matter of minutes. During this long waiting period the lorries and their drivers are standing idle and adding to the congestion in the dock area, for unlike railway wagons, lorries cannot be held in a siding until required.

Water Conveyance

Water conveyance is very suitable for homogeneous consignments which do not require a lot of sorting and examination. Providing they arrive in good time, craft do not present the same complicated organisation problems as land conveyances. The craft provide their own pitches which can be manœuvred easily under the heads of the ships' derricks. The men in charge of the lighters supervise and in some cases assist in the loading of their cargoes. Difficulties are sometimes created by craft crowding round the vessel waiting their turn to load. The ship's clerk can deal with such congestion by informing the lighterman, or whoever else is in charge of the craft, of the order in which they will be discharged.

Flow of Cargo

The quay staff should aim at providing a regular and steady flow of cargo to the ship's side so that the ship (1) does not wait for cargo thus ensuring that stevedores, ships' derricks and quay cranes are not kept idle during working hours, and (2) receives the cargo in the order required for stowage by the Cargo Superintendent or the Chief Officer or whoever else is responsible for stowage. Alterations in the stowage arrangements after they have been made by the responsible officers cause delays and disorganises the workers. In addition to which make-shift stowages are rarely as good as the original.

The loading circumstances described above for general cargo cannot be produced by direct loading and the aim of the quay staff should be to accumulate sufficient cargo in the transit shed or area before loading commences to give the ship a good start. Thereafter arrangements should be made to ensure a flow of cargo each day to the transit shed or area to replace what has been loaded to the ship on the previous day, until delivery of all the cargo for loading from the quay has been received.

Assuming that the cargo is available, then the amount which may be accumulated before loading commences is often governed by the size of the transit shed or area. It is difficult to generalise about the proportion of the cargo required before loading commences because of the great differences in the sizes of cargo ships, which vary from those taking a day or less to load to those requiring ten days or more.

The matter can probably be best discussed by considering the hypothetical case of a ship loading 6,000 tons dead weight of general cargo and expecting to complete in nine or ten days. To ensure a good start such a ship would require enough cargo in the transit area to guarantee at least 4 continuous days working. What tonnage constitutes four days' work depends on the type of cargo, but it is reasonable to assume in the case under consideration that the heaviest loading days would probably be the third and fourth.

Interior of Transit Shed. Cases stacked so that marks and numbers may be easily and quickly read

The first two days would be spent loading the cargo into the holds above the turn of the ship's sides and above the tunnel shaft top in the after-holds. (The tunnel shaft is the casing enclosing the propellor shaft which runs from the ship's engines to her propellor or screw at the after-end. A twin-screw ship has two tunnel shafts. The space between these tunnel shafts is known by stevedores as " the coffin "). In terms of gross tons the operator might estimate that 300-400 tons might be loaded on the first day, 600 on the second day and 1,000 tons on each of the third and fourth day, i.e., 3,000 tons in four days. In these circumstances the aim should be to get 3,000 tons in the transit area, always providing, of course, that there is sufficient accommodation, before the ship starts. If some of the cargo is to come from craft or is to be loaded direct then these factors need to be taken into consideration. It is reasonable to expect, in normal circumstances, for loading to slow down after about the fourth day, for then the cargo will be getting nearer to the between ('tween) deck ceilings. Thus stowage and working space will automatically become restricted and the stowing operations in consequence will become more difficult and slower. Towards the end of loading the smaller holds will finish and the daily tonnage for the ship will drop in consequence. The last day will probably be spent loading, sheeting and lashing down any deck cargo.

Arrival of Cargo in Shed

As has already been said the cargo for bottom stowage, which is usually the heaviest, should be placed at the front of the shed or on the quay apron. The cargo for middle stow should come next and the top stowage should be stacked at the rear. In practice such ideal arrangements are rarely if ever attained, although in wartime under vastly different conditions something like them was

Port Operation—*continued*

achieved, but the quay staff should adopt them as their standard and go as near as the circumstances of commercial practice, customs of the port and trading conditions will allow.

High Piling

Where floor space permits, cargo which is to be man-handled should not be high piled. The height at which cargo commences to be high piled varies as between ports and countries, but in actual practice it is the height to which a man can pile and from which he can unpile when he is standing at ground level. This renders the consignments easily accessible and obviates the necessity for labourers clambering over the piles, in order to break them down, which has the effect of slowing down the work and damaging the cargo.

Where the cargo is stacked on pallets the same considerations do not apply, but even then care must be taken to ensure that consignments for early loading are not piled beneath cargo required for later stowage.

Care in Stacking

The stacking of cargo in the shed should receive careful treatment. Slap-dash piling which is often countenanced on the grounds that the cargo will not be long awaiting shipment, should not be permitted.

Cases and similar regular-shaped packages should be properly bonded at the corners and stowed the right way up so that marks and numbers can be easily recognised. Packages should never be stacked on their edges or corners.

Packages which are to be lifted by cargo-handling gear should be stowed on "stickers," i.e., regular shaped pieces of timber, so that the gear can be easily slid underneath them without first lifting them. Where such packages are piled, stickers should be placed between each tier for the same reason.

Frail or easily-damaged packages should not be stowed under heavier ones.

Barrels, drums and similar containers, should be stacked " bung up " and where there is a chance of them leaking (" leakers "), piled away from other cargo.

Bagged grain should be stacked on tarpaulins which should be turned up round the stacks and " tucked in " between the first and second tiers. This permits of rapid sweeping after the stack has been unpiled, prevents " loose collected " from being trampled over the shed floor and keeps the sweepings relatively clean.

Cargoes stacked in the open, likely to suffer damage from rain, should be piled on dunnage boards and sheeted over with tarpaulins.

Dirty cargoes, such as fish, oil, ghee, paint, should be segregated from other cargoes.

The same applies to cargoes which are easily tainted, e.g., foodstuffs should be kept away from those giving off strong odours, e.g., oils, wet hides and tarred rope. Many foods themselves give off strong odours, e.g., onions, oranges and apples, and should be stowed away from other foodstuffs, e.g., tea and spices, which are spoiled by such contacts.

Valuable cargoes such as mail, spirits, etc., should be kept in the lock-up cage.

Cleaning and Hatch Boards

Before loading commences the ship should be cleaned, the derricks rigged and the hatch boards stowed neatly on deck. Untidily stacked hatch boards form unnecessary obstructions on the decks, which are restricted spaces in any case, and constitute a danger to personnel using the decks, particularly at night.

Laying Out Gear

Cargo-handling gear should be laid out on the quay opposite each hatch and carefully checked as to suitability and condition.

Stowage

The stowing of cargo in ships calls for considerable care, skill and experience on the part of the stevedores engaged in placing the packages in position in the holds. The difference between a good stevedore and a bad stevedore generally depends on the care which he exercises in handling the cargo. Cases, cartons and similar packages should be placed in position and not thrown down, neither should they be stowed so that there are unnecessary spaces between them. Stowages should be tight. Loose stowages not only waste space but cause the cargo to move unnecessarily when the ship is at sea thereby increasing the risk of damage.

Dunnage

One of the most important factors in producing good stowage and ensuring the safe passage of the cargo while at sea, is the correct use of dunnage.

Dunnage is usually timber boards or laths about 1-in. thick, 3-in. to 6-in. wide and from 5 to 12-ft. long. It is used (1) to prevent cargo being damaged by the water which overflows from the bilges or double bottom tanks, (2) to protect cargo from the moisture which condenses on the ship's sides and bulkheads, (3) to protect cargo from leakages from other cargo, (4) to minimise the movement of cargo and the risk of chafing when the ship is at sea, (5) to fill in broken stowage, (6) ventilation.

Dunnage may be laid athwartships or fore and aft. It is placed between the tiers of cargo to prevent movement and chafing. It is not required between strong and regularly shaped packages, e.g., small cases, but it is used to " level off " uneven floors caused by the stowage of packages differing in size and shape. It is also used between tiers of drums and between drums and other cargo to prevent the sharp edges of the drums cutting into one another or the other cargo stowed in the lower and/or upper tier. It should be placed under heavy or awkward packages not fitted with lifting lugs to enable the cargo-handling gear to be slipped into position when the cargo is being discharged.

Chocking

In order to prevent some packages from shifting because of the movement and rolling of the vessel when she is at sea, it is necessary to fix them in position by means of timber (dunnage wood is usually employed but for heavy articles, e.g., locomotives, much stouter timber is used) or suitable packages from the cargo, e.g., bagged cargo and baled goods. When the latter method is employed particular care must be used in selecting the type of package to ensure that it does not itself suffer damage. The holding of cargo in position by these means is known as chocking.

Broken Stowage

Chocking by using other cargo also serves the useful purpose of taking up spaces between packages which would otherwise be wasted, the space taken up in this manner is known as " broken stowage."

Lashing

Cargo which cannot be held in position by choking is usually lashed down. Cordage may be used but more generally, particularly for heavy packages and cargoes which move easily, e.g., vehicles, lashing wire is used. The packages are lashed by means of this wire to cleets fixed to the decks. To make the lashing as tight as possible bottle screws (turn-buckles) are used. The wires are seized (joined) to the bottle screws which are in turn shackled to the cleets. Bottle screws are so constructed that they can be turned by hand to tighten the wires.

Bottle Screws

A bottle screw is an open-sided cylinder threaded at each end to receive a screw pin. The screw pins used are fitted with an eye at one end, so that when they are screwed into the cylinder, one may be seized to the wire and the other one shackled to the cleet. When the package is first lashed, the pins should be separated by as big a space as possible, so that any slack which may occur after the ship is at sea can be taken up by merely turning the cylinder of the bottle screw, for obviously once the screws are turned into the cylinder as far as they will go, any further tightening will necessitate relashing.

Shifting Boards

Some cargoes are prone to shift with the movement of the ship when she is at sea. This may not only cause damage both to

Port Operation—continued

the cargo which shifts and other cargo in the same hold, but also jeopardise the safety of the ship by causing her to take a list. To prevent this movement of cargo, wooden partitions made of boards known as "shifting boards" are used. Bulk grain is always liable to move unless held in position. When shifting boards are used for bulk grain they also prevent the grain from infiltrating into other parts of the ship.

Covering Up

After the loading of the holds is completed, they are "covered up" by means of beams and hatch boards. Beams are T-shaped girders which are fitted athwart the hatchway by lowering them into slots fitted to the inside of the coaming. They are lifted into position either by ship's gear or quay cranes. To facilitate lifting and fixing into position the beams are made with holes at the ends through which shackle pins or bolts may be passed. Hatch boards are laid fore and aft on the beams. Hatchways are rendered water-tight by stretching tarpaulins over them. These are held in position by means of metal bars, laid along the outside of the coaming, to keep the tarpaulins taut wedges are driven between them and the metal bars.

It is the practice to cover up between working periods, to protect cargo from inclement weather and against pilferage.

When heavy cargo is to be stowed on hatch boards, as is frequently the case, dunnage wood is laid over the hatch boards for strengthening purposes

(To be continued)

Additional Reading:

Nicholl's Seamanship and Nautical Knowledge—Brown. Chapter XVI Stowage. Handling and Transport of Ship Cargoes—Captain Pierre Garoche. Chapters IV—VI.

British Transport Commission

Members of the Docks and Inland Waterways Executive

The Minister of Transport, the Rt. Hon. Alfred Barnes, M.P., has announced that the following have accepted his invitation, made after consultation with the British Transport Commission, to become Members of the Docks and Inland Waterways Executive:—

Chairman: Sir Reginald Hill, K.B.E., C.B.

Members (full-time): Mr. Robert Davidson, M.Inst.T.; Mr. John Donovan; Sir Robert Letch, M.Inst.T.

Members (part-time): Mr. George Cadbury, M.Inst.T.; Sir Hector McNeill; Sir Ernest Murrant, K.C.M.G., M.B.E.

Sir Reginald Hill, who has been a Deputy Secretary of the Ministry of Transport in charge of inland transport (railways, roads, docks, and canals) since 1940, has served in that Department since its inception in 1919. Before joining that Department he served in the Board of Trade. In 1944-5 he was a member of the SHAEF Shipping Committee. He is Chairman of the Central Transport Committee.

Mr. Robert Davidson has been General Manager and Engineer of the Leeds and Liverpool Canal Company since 1925. He is President of the Canal Association, and Chairman of the North Western Regional Canal Committee. He is a Vice-President of the Institute of Transport.

Mr. John Donovan has for many years been associated with dock labour questions. Since 1941 he has been National Secretary of the Docks Group of the Transport and General Workers' Union, is one of the Secretaries of the National Joint Council for the Port Transport Industry, and is a member of the National Dock Labour Board.

Sir Robert Letch has served with the Port of London Authority since 1915 (he was formerly Assistant General Manager). He is Chairman of the National Association of Port Employers, and Joint Chairman of the National Joint Council for the Port Transport Industry. He is also a Member of the Institute of Transport. During the war he held appointments under the Ministry of Transport as Executive of the Clyde Anchorages Emergency Port, as Regional Port Director for the Clyde (and later for Scotland), 1941-42, and as Regional Port Director for the North-Western Area, 1942-45.

Mr. George Cadbury was for many years Managing Director of Cadbury Brothers, Limited. He is Chairman of the Severn Carrying Company, one of the River Severn Commissioners, President of the Canal Carriers' Association, and a member of the Central Canal Committee. He is also a Member of the Institute of Transport.

Sir Hector McNeill has been Lord Provost of Glasgow since 1945. He was Deputy District Commissioner for Civil Defence for Glasgow and the West of Scotland from 1941 to 1945, and Regional Port Director for Scotland in 1945-46.

Sir Ernest Murrant is President of the Chamber of Shipping of the United Kingdom, and Chairman of the General Council of British Shipping. He is Chairman of Furness, Withy and Company, Limited, and chairman or a director of various shipping, insurance, ship-building and finance companies. During the war he was the representative of the Minister of War Transport in the Middle East.